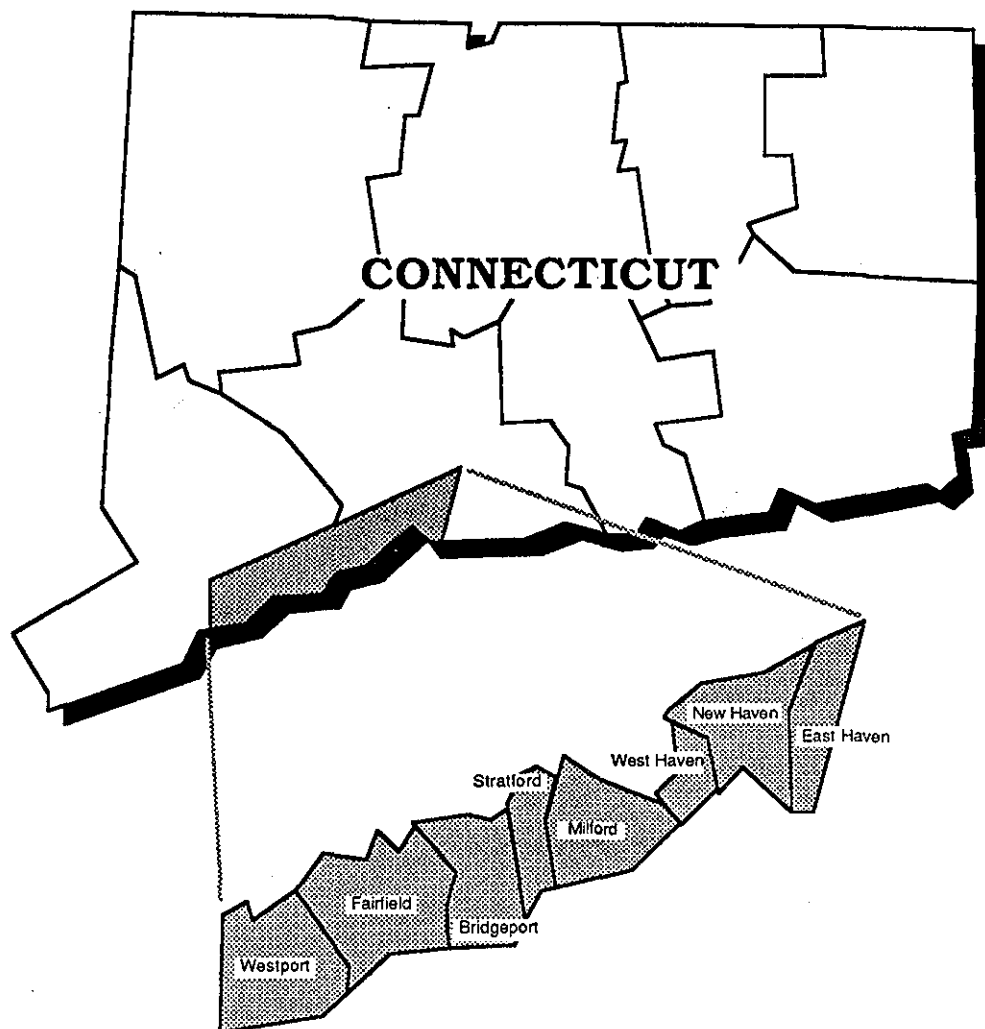


Reconnaissance Report

Water Resources Study
Long Island Sound

*Lead
Army* 6-10-88

Tidal-Flood Management West Central Connecticut



US Army Corps
of Engineers

New England Division
June 1988

**WATER RESOURCES STUDY
LONG ISLAND SOUND**

**TIDAL-FLOOD MANAGEMENT
WEST CENTRAL CONNECTICUT**

RECONNAISSANCE REPORT

JUNE 1988

**Department of Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254-9149**

RECONNAISSANCE REPORT
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LONG ISLAND SOUND
TIDAL-FLOOD MANAGEMENT
WEST CENTRAL CONNECTICUT

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EXECUTIVE SUMMARY

This study identifies and evaluates the feasibility of alternative tidal flood management measures in eight communities along the west central Connecticut coast from East Haven to Westport. The study was authorized by a Resolution of the Senate Public Works Committee, adopted 22 September 1970, and conducted as a result of a basic regional plan developed through the Long Island Sound Study. That study was completed under the direction of the New England River Basins Commission.

This Reconnaissance effort has investigated coastal flood damage sustained within the study area to determine if there is Federal and State interest in the implementation of flood damage reduction measures. The reconnaissance study phase is the first of a two-phase planning process and provides the basis for continuing into the feasibility or second phase. The feasibility phase includes a detailed investigation of alternative solutions, selection of a plan, and results in a report which forwards recommendations to Congress.

The Connecticut coastline is susceptible to tidal flood damage caused by hurricanes and other severe storms. Historically, the September 1938 and August 1954 hurricanes caused both the highest tide levels and most property damage. In the study area alone, it is estimated that a repeat of the 1938 and 1954 events would cause over \$97 million and \$64 million in losses respectively. Although Connecticut has not experienced severe coastal flooding for over 30 years, the potential for damage remains. If the tidal surge associated with Hurricane Gloria in September 1985 had occurred during high tide rather than at low tide, the resulting tide levels would have been much higher.

Numerous meetings with State of Connecticut Department of Environmental Protection officials and representatives of the communities of Westport, Fairfield, Bridgeport, Stratford, Milford, West Haven, New Haven and East Haven identified over 30 flood prone sites. Initial evaluation of these areas to determine the potential for significant tidal flood damage reduced the number of sites eligible for Federal participation to 21. Plan formulation studies in these areas determined that further study is warranted at five sites located in the communities of Westport, Milford and Fairfield.

In the Town of Westport, two sites have been identified for further study, the Saugatuck Shores area and the low lying area adjacent to Compo Cove. Evaluation of alternative methods to reduce flood damages in these areas determined that floodproofing by raising (elevating) structures is economically justified.

Evaluation of coastal flooding in the community of Milford determined that further study was justified at the Bayview Beach and Point Beach areas. Formulation of plans to protect properties in the Bayview and Point Beach areas determined that floodproofing of structures was the only economically justified plan.

Further study in the communities of Westport and Milford will be conducted under Section 205 of the 1948 Flood Control Act, as amended. Improvements considered fall within the Section 205 cost limitation of \$5 million. In addition, the need for specific congressional budget action or project authorization which is necessary for larger projects is not required, thereby accelerating further studies and potential project construction.

In the Town of Fairfield, flood prone areas adjacent to Ash Creek, Jennings Beach and Pine Creek were combined into one large contiguous study area. Studies of potential solutions determined that raising structures would be economically justified. Coastal projects to prevent inundation of this area, such as dune restoration and construction, were not justified. However, since the Town has constructed some low dikes further inland, particularly to prevent recurring flooding in the Pine Creek area, the possibility of augmenting these protective measures was identified as an alternative that should be evaluated in further detail during the feasibility phase of study.

Inasmuch as current estimates of project costs in Fairfield exceed the Section 205 limit, feasibility phase studies in this area are recommended under the Long Island Sound Study authority. As required under the Water Resources Development Act of 1986 (P.L. 99-662), subsequent detailed feasibility studies will be conducted on a 50-50 cost sharing basis with the non-Federal Sponsor, the State of Connecticut.

SECTION I

INTRODUCTION

The completion of the Long Island Sound Study (LISS) in 1975 by the New England River Basins Commission brought forth recommendations to investigate tidal flooding in several communities along the Connecticut coast, including Westport, Fairfield, and Stratford. The State of Connecticut Department of Environmental Protection (DEP), in a 1983 letter to the New England Division, Corps of Engineers also recommended new studies to delineate flood management alternatives for coastal areas, including the communities of Fairfield, Milford, West Haven, New Haven, and East Haven. The City of Bridgeport was later added for a total of eight communities along the west central Connecticut coast from Westport to East Haven to be studied.

This reconnaissance study conducted a preliminary evaluation of flood damage areas within these eight communities to determine if there is a Federal and State interest in the implementation of tidal flood damage reduction measures. This study included evaluation of different combinations of non-structural and structural techniques for flood damage reduction.

STUDY AUTHORITY

This study is authorized by a Resolution of the Senate Public Works Committee, adopted 22 September 1970, which states:

"That the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act approved June 13, 1902, be and is hereby requested to review the report on the Land and Water Resources of the New England-New York Region, transmitted to the President of the United States by the Secretary of the Army on April 27, 1956, and subsequently published as Senate Document Numbered 14, Eighty-fifth Congress, with a view to determining the advisability of improvements in Long Island Sound, New York and Connecticut in the interest of flood control, navigation and related purposes with due consideration for enhancing the quality of the environment."

PURPOSE AND SCOPE

To provide a planning and management tool for the development of alternative solutions to reduce tidal-flood damage, this report considers the desirability of implementing recommendations contained in previous reports and/or adopting further measures for reducing the potential for tidal-flood loss. As the beginning of a two-phase planning process this report identified the problems, needs, opportunities, and potential solutions. It determined the significance of existing or potential tidal-flood damage, the views of local interests concerning further investigation and whether further Federal participation is warranted.

This reconnaissance study phase provides a basis for to evaluating the merits of continuing into the feasibility (second) phase.

PRIOR STUDIES

In 1971, the U.S. Water Resources Council designated the New England River Basins Commission to conduct a comprehensive water resources study of the Long Island Sound area in conjunction with the State of Connecticut, the State of New York and several Federal agencies. As a result of this study, a series of reports entitled Land Use, Water Management, Shoreline Appearance and Design, Erosion and Sedimentation, Flood Damage Reduction, Recreation, Fish and Wildlife, Marine Transportation, Minerals, and Power and the Environment were prepared by various Federal agencies. Information contained in those earlier reports has been utilized in the preparation of this report.

The Long Island Sound Comprehensive Report, People and the Sound, A Plan for Long Island Sound (July 1975), is an approved regional plan of the New England River Basins Commission. The Comprehensive Report recommends that the Corps begin an early action program of harbor debris cleanup, including removal of dilapidated or rotting piers and abandoned, grounded vessels. The priority harbor debris cleanup areas along the Connecticut coast are New Haven, Bridgeport, Norwalk and Stamford Harbors. It also recommends that the Corps study an additional six Connecticut tidal flood prone areas, with emphasis on nonstructural alternatives to prevent or reduce flood damages, as follows: Montville (Montville Station Area), New London (Ocean Beach Area), Old Lyme (Point of Woods Area), Stratford (Great Meadows Industrial Area), Fairfield (Pine Creek, Fairfield Beach, Jennings Beach and Ash Creek Areas) and Westport (Saugatuck River Area including Saugatuck Shores and Central Business District).

Other reports reviewed and evaluated as part of the reconnaissance effort are:

- "Shore Protection Manual," Volumes I, II, and III dated 1973, prepared by the U.S. Army Corps of Engineers, Coastal Engineering Research Center.
- "Long Island Sound Regional Study Land Use Inventory Report" dated February 1974 prepared for the U.S. Department of Housing and Urban development by Ralph M. Field and Associates.
- "Long Island Sound Interim Memo No. COE 2 "Tidal Hydrology" dated June 1973, prepared by the U.S. Army Corps of Engineers, New England Division.
- "Connecticut Coastline Study" dated July 1976, prepared by the U.S. Army Corps of Engineers, New England Division.
- "Floodproofing Non-Residential structures", dated May 1986, prepared by the Federal Emergency Management Agency.
- "Design Manual for Retrofitting Flood-prone Residential Structures", dated September 1986, prepared by the Federal Emergency Management Agency.
- "Elevated Residential Structures", dated March 1984, prepared by the Federal Emergency Management Agency.

- Long Island Sound Regional Study "An Economic Perspective, A Special Report," dated July 1974, prepared by The Economic and Demographic Work Group of the Long Island Sound Regional Study.

- Hurricane Survey Interim Report "Connecticut Coastal and Tidal Areas" dated 22 May 1964, prepared by the U.S. Army Corps of Engineers, New England Division.

ONGOING STUDIES AND INVESTIGATIONS

Hurricane Evacuation Study - In November of 1986, the Corps of Engineers, at the request of the Federal Emergency Management Agency (FEMA) and the State of Connecticut, Office of Civil Preparedness, initiated a hurricane evacuation study for the coastal communities of Connecticut. The study is part of an ongoing National program to identify the portions of the coastal United States vulnerable to hurricane flooding. The Corps of Engineers participates in this program under the authority of the Flood Plain Management Services (FPMS) Program.

The purpose of the Connecticut Hurricane Evacuation study is to identify the areas and population within the entire Connecticut coastal area vulnerable to the flooding effects of a potential landfall hurricane and to estimate the time and conditions required to safely evacuate the population at risk. The study utilizes a mathematical hurricane storm surge model called SLOSH to determine the magnitude of the potential coastal flooding. The SLOSH model was developed by the National Weather Service and has been performed for the Connecticut study by the National Hurricane Center. The results of the model are used to develop evacuation maps for each of the coastal communities based on selected hypothetical hurricane scenarios. Detailed investigations will be performed for each scenario to determine the location of the population at risk, their probable evacuation destination, potential evacuation concerns and an estimate of the total time required to safely evacuate the vulnerable areas. The final results of the study will be documented in a technical data report. This report will provide the pertinent information required for the state and local communities to update or refine their hurricane response plans.

Shore Protection Studies - The New England Division of the Corps of Engineers has conducted several studies in West Central Connecticut under the authority granted in Section 103 of the 1962 River and Harbor Act as amended. The Authority provides for the Chief of Engineers to construct small shore protection projects. Projects currently under study are itemized below.

Sea Bluff Beach, West Haven, CT - The Feasibility Study, completed in April 1987, recommended a plan to reduce storm damage and provide backshore erosion control along an approximate 1,000 foot reach of Sea Bluff Beach. The plan entails beach widening by direct placement of suitable sandfill along approximately 1,000 feet of shorefront and providing for a 50-foot wide level beach berm at elevation 12.0 mean low water and a 122-foot wide dry beach above the mean high waterline. Also included is the reconstruction of an existing rock groin structure, and a beach monitoring and renourishment program. The project is estimated to have a first cost of \$321,000 which includes the first year of periodic nourishment. The project is currently undergoing detailed design.

Prospect Beach, West Haven, CT - A feasibility study is currently underway to reduce damages and flooding by controlling erosion along approximately 4,300 feet of Prospect Beach in West Haven, CT. The feasibility report will outline the problem and its causes and present a plan for protecting the threatened properties. Present analysis indicates that the most technically and economically feasible and environmentally and socially acceptable plan may be one of beach restoration between Ivy Street and a groin structure west of Tyler Street. The plan would provide protection to the backshore and landward road and utilities and reduce or prevent flooding from major storms and prevent road closures.

Woodmont Beach, Milford, CT - Beginning in April 1988 an 18-month feasibility study has been underway to determine the feasibility of controlling erosion and reducing damages to an approximately 1,500-foot reach of Woodmont Beach between Clinton Avenue and Bonsilene Avenue. Improvement plans under consideration are beachfill, revetment and a combination of fill and revetment.

Corps' Support-for-Others Program - The New England Division of the Corps of Engineers completed a study in November 1987 for the purpose of defining the nature of the erosion problem at Savin Rock Beach and to investigate possible solutions. The report was conducted at the request of the City of West Haven, CT and was funded by the City and the State of Connecticut Department of Environmental Protection. The study area extends from Washington Avenue eastward a distance of about 1,700 feet. The report describes five improvement plans and their implications on possible community goals and would serve as a preliminary decision document for the City of West Haven with respect to dealing with the erosion problem at Savin Rock Beach.

REPORT AND STUDY PROCESS

The two phase planning process provides a mechanism to accommodate significant non-Federal participation in Corps feasibility studies contributing to an efficient and effective planning process. The reconnaissance (first) phase provides a preliminary indication of the potential of the study to yield solutions which could be recommended to the Congress as Federal projects. The results of the reconnaissance phase provide the basis for decision-making within and outside the Corps and the Administration to evaluate the merits of continuing the study and allocating feasibility (second) phase funds. This reconnaissance phase has accomplished the following:

- (1) Defined the water and related land resources problems and opportunities of the study area.
- (2) Developed the objectives and constraints of the study based on identified needs and opportunities.
- (3) Identified measures to address these needs and opportunities.
- (4) Developed alternative plans to meet these problems and opportunities.

- (5) Conducted a preliminary evaluation and screening of alternative plans, to include a preliminary determination of likely impacts and non-Federal views and preferences.
- (6) Described and discussed the likely array of alternatives to be carried into the feasibility phase, and identified a solution that is feasible and implementable.
- (7) Assessed the level of interest in and support for identified potential solutions, and obtained concurrence from the non-Federal sponsor of their understanding of cost sharing requirements.
- (8) Determined and recommends what additional planning should be undertaken, based on a preliminary appraisal of the Federal and non-Federal interest. This appraisal considered costs, benefits, impacts and support for the identified potential solutions. To be supported by the non-Federal Sponsor, potential solutions were consistent.
- (9) For areas where further study is recommended, it recommends and initiates development of a Feasibility Cost Sharing Agreement to conduct more detailed studies in partnership with the non-Federal sponsor.

The planning process followed during each stage incorporates the four basic planning functions of problem identification, formulation of alternatives, impact assessment and evaluation.

Problem Identification - This task served to identify the tidal-flooding problems to be addressed and to establish study planning objectives. This included the development of a regional profile of environmental, social and economic conditions for the study area. The study objectives guided formulation of alternatives, whereas the regional profile served as a base condition for determining impact assessment and evaluating capabilities of alternatives.

Formulation of Alternatives - Formulation was the process of developing alternative tidal-flood plain management systems which responded to identified problems, concerns and the study area planning objectives. All potential measures available for problem solution were identified, and both structural and nonstructural measures were considered in developed plans.

Impact Assessment - This function included tasks required to determine the effect of each alternative plan on existing social, economic and environmental conditions. These effects were measured over the impact zone.

Evaluation - The evaluation function involved work tasks needed to measure and compare the relative values of each alternative plan, particularly in response to achieving the study objectives. Benefits and losses associated with the development of each plan were described in order to effectively analyze possible trade-offs between plans and to recommend further study or action.

SECTION II

PROBLEM IDENTIFICATION

EXISTING STUDY AREA CONDITIONS AND NATURAL RESOURCES

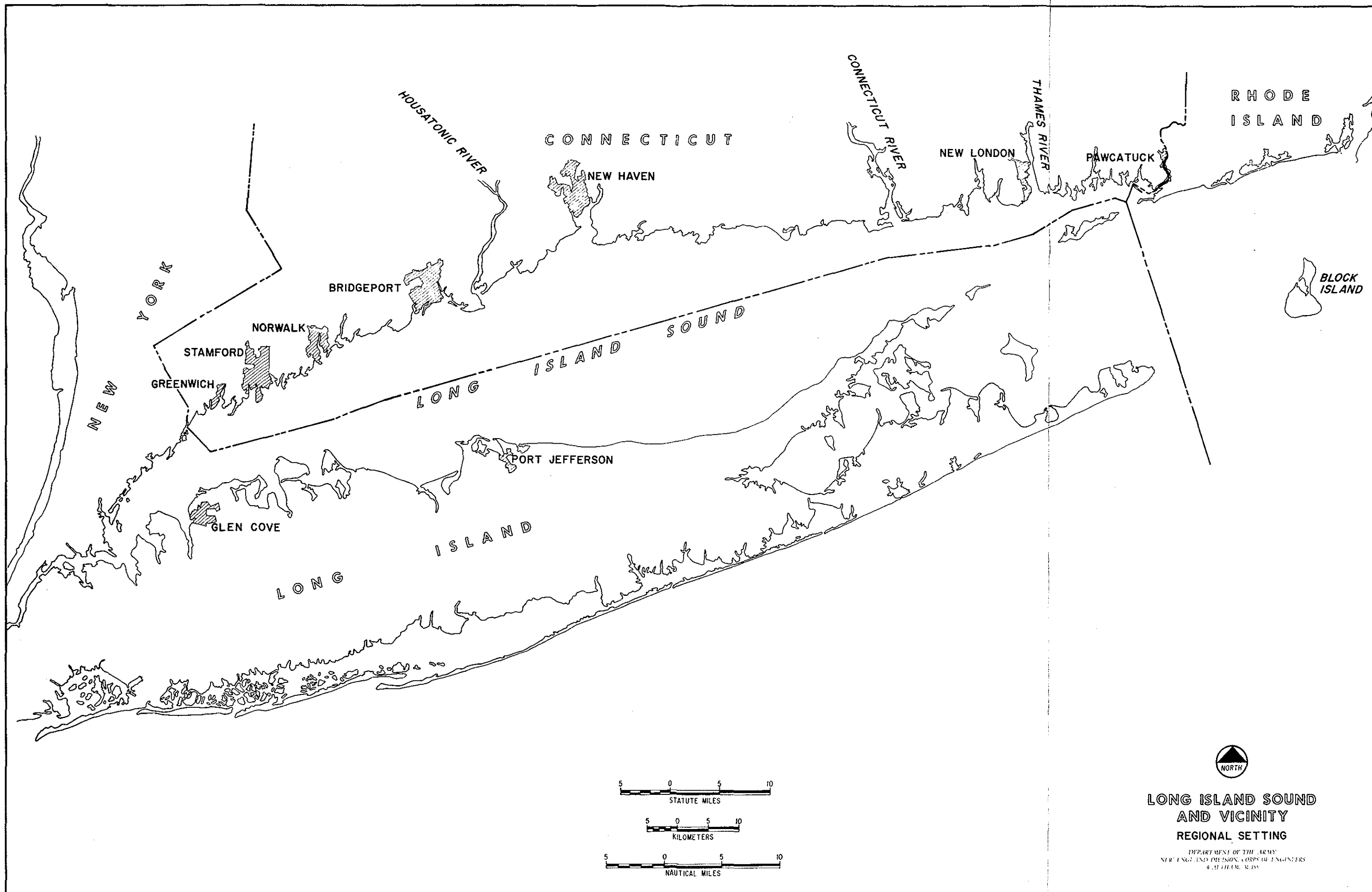
Area Profile - Connecticut is a popular vacation and tourist area and is aptly termed the gateway to New England. The State is approximately 100 miles long in an east-west direction, and 50 miles wide in a north-south, inland, direction. The entire southern boundary of the State is the shore of Long Island Sound, a rather narrow, sheltered arm of the Atlantic Ocean (see Plate 1). The fact that Connecticut is located in a temperate latitude and that the waters of Long Island Sound are generally calmer and warmer than along the exposed ocean shores of the neighboring states has induced intensive development of the water front. A further attribute of the State is that the flat plain which extends generally a mile or more inland is well suited to resort development. The Connecticut shore is also very irregular, about 165 miles long, dotted with bays, coves, promontories and near-lying islands, all of which add variety to the area and to its value for resort and residential development.

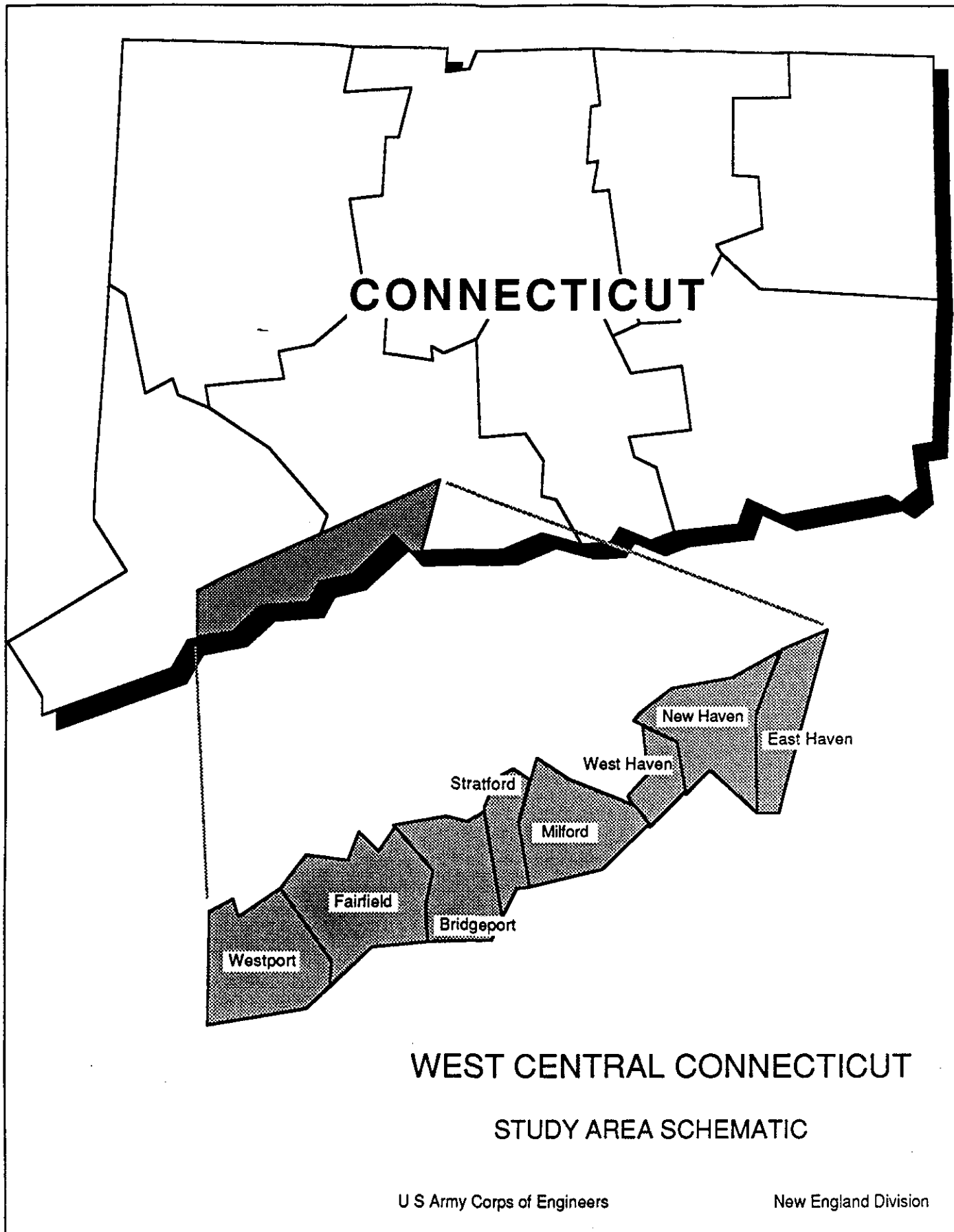
The study area (shown on Plate 2) is located along the north shore of Long Island Sound in the west-central portion of Connecticut. The area extends westerly from Mansfield Point in East Haven, along approximately 49 miles of shoreline, to Saugatuck Shores in Westport. This area includes the shoreline of the towns of East Haven, Stratford, Fairfield, and Westport, and the cities of New Haven, West Haven, Milford and Bridgeport. These eight communities had a combined population of approximately 537,000 in 1987 and, based on population projections developed by the State of Connecticut, this population is expected to increase to over 552,000 by the year 2030 (Table 1). Development in these eight communities ranges from rural and residential to commercial and industrial in nature.

TABLE 1

COMMUNITY SHORELINE LENGTH AND POPULATION

Community	Shoreline Length (Miles)	Population Actual 1980	Population Approx. 1987	Population Estimated 2030
East Haven	2.3	25,028	25,000	26,900
New Haven	7.4	126,109	128,000	138,300
West Haven	5.3	53,184	55,000	58,500
Milford	9.7	50,898	52,000	55,100
Stratford	5.4	50,541	51,000	55,600
Bridgeport	5.9	142,546	144,000	145,700
Fairfield	4.7	54,849	55,000	48,300
Westport	8.5	25,290	27,000	23,900





General Environmental Setting - The coastline bordering Long Island Sound in the study area consists of a diverse and productive coastal ecosystem. The coastal waters, barrier beaches and intertidal areas provide important habitat for many species of wildlife, and support commercially valuable fishing and shellfishing industries. Development along the coastline from Westport to New Haven includes both year-round and summer homes and large industrial and commercial complexes in New Haven, Milford, Stratford and Bridgeport.

Topography and Geology - The coastal area of Connecticut is a glaciated zone underlain by crystalline bedrock which slopes southward at 50 feet per mile (U.S. Dept. of Commerce, 1980). New Haven is comprised of shales, sandstones and limited exposures of trap rock. Till covers most of the land surface, usually compacted into a hardpan, and stratified drift overlies the till in the major stream valleys along the coast (NERBC, 1981).

The terrain of this portion of west central Connecticut is low and flat, with average elevations less than 200 feet, with well-developed floodplains (NERBC, 1981). Areas 15-20 miles inland from the coast are characterized by low, gently rolling hills, with average elevations of 250-750 feet (NERBC, 1981). The Connecticut coastline is very irregular, characterized by broad, rocky points separated by coves with sandy or rocky beaches.

Water Quality - Long Island sound receives waters from eleven river basins, with the Housatonic River, the Connecticut River and the Thames River emptying directly into the Sound. The harbors and coastal waters, therefore, are affected by numerous sources and varying levels of water quality conditions. Typical problems in the various estuaries and harbors include low dissolved oxygen concentrations and high levels of coliform bacteria, solids, nitrogen and total phosphorus (U.S. Dept. of Commerce, 1980). Over the years, the water has improved through the efforts of state and local management programs.

Table 2 describes the State of Connecticut water quality classifications for the study area, and Table 3 shows the state water quality classifications at sites within the study area. Any site with two classifications noted for that area gives first the existing classification, then the desired classification.

TABLE 2

WATER QUALITY STANDARDS,
CONNECTICUT DEPARTMENT OF ENVIRONMENTAL PROTECTION, 1980, 1982

Class SA or A Suitable for all seawater uses including shellfish harvesting for direct human consumption (approved shellfish areas), bathing, and other water contact sports; and may be subject to absolute restrictions on the discharge of pollutants.

Class SB or B Suitable for bathing, other recreational purposes, agricultural uses; certain industrial processes and cooling and shellfish harvesting for human consumption after depuration; excellent fish and wildlife habitat and good aesthetic value.

Class SC Limited suitability for fish, shellfish and wildlife habitat, for recreational boating and industrial cooling; good aesthetic value; and not suitable for bathing.

Class SD May be suitable for bathing or other recreational purposes, certain fish and wildlife habitat, certain industrial processes and cooling; may have good aesthetic value. Present conditions, however, severely inhibit or preclude one or more of the above resource values.

Class GB Groundwater quality-may not be suitable for potable use unless treated because of existing or past land uses. May be suitable for receiving certain treated industrial wastewaters when the soils are an integral part of the treatment system.

TABLE 3

STUDY AREA WATER QUALITY CLASSIFICATIONS

SOURCE: CT Dept. of Environmental Protection,
Water Compliance Unit, 1981 and 1982

East Haven	
City of East Haven	GB
West Silver Sands Beach	SC/SB
Shell beach	SC/SB
New Haven	
Inner Harbor	SC/SB
Outer Harbor	SC/SB
Morris Creek	SB/SA
West River	SB/SA
West Haven	
Old Field Creek	SB/SA
Cove River	SB/SA
Oyster River	SB/SA
Milford	
Burwells Beach	SC/SB
Calf Pen Meadow	GB
Fort Trumbell/Silver Beaches	SB
Inland from Seaview Ave./Broadway	GB
Mouth of Housatonic River	SC/SB
Stratford	
Lordship Beach	SC/SB
Ferry Creek	B/A
Bridgeport Harbor	SC/SB
Fairfield Harbor	
Ash Creek	SC/SB
Jennings Beach	SC/SB
Fairfield Beach	SC/SB
Pine Creek	SB/SA
Westport	
Saugatuck Shores	SC/SB
Compo Beach/Compo Cove	SA

Coastal Resources - The study area is designated as the Coastal Hardwoods Zone, the Western Coastal ecoregion (Dowhan et al, 1976). The dominant tree species include Black, Red, and White Oak (*Quercus velutina*, *Q. rubra*, and *Q. alba*), Hickory (*Carya* sp.), Tulip poplar (*Liriodendron tulipifera*), Black Cherry (*Prunus serotina*), Sassafras (*Sassafras albidum*) and Hemlock (*Tsuga canadensis*) (Dowhan et al, 1976). There are numerous shrubs and vines in the open forests and woodlands, and red cedar (*Juniperus virginiana*) is dominant in early phases of old field development (Dowhan et al, 1976). Red maple (*Acer rubrum*) is a dominant inland wetland species.

There are no unique farmlands in the study area. New Haven County has 42,500 acres, and Fairfield County has 22,500 acres of prime farmland, with little to none specifically in the study area (SCS, 1981). Small acreages are found in Sherwood Island State Park, in Fairfield, and near the municipal airport in Bridgeport.

The coastal area tidal wetland systems are made up of salt and brackish marshes. The dominant low marsh vegetation is salt marsh cordgrass (*Spartina alterniflora*), and the upper marsh is characterized by a mixture of salt marsh hay (*Spartina patens*) and Spikegrass (*Distichlis spicata*). The high edge of the marsh supports Black Grass (*Juncus gerardi*) and Switchgrass (*Panicum virgatum*). Marsh elder (*Iva frutescens*), and sea lavender (*Limnium limnium*) are found in the transition zone between the high and low marshes. In areas where the salinity regime has been altered by tidal gates or filling activities the brackish reed (*Phragmites australis*) is dominant. As the salinities diminish upstream, brackish plants become dominant, and include cattails (*Typha* sp.) and various species of bulrushes (*Scirpus americana*, *S. olneyi*, *S. validus* and *S. fluviatilis*).

The beaches and dunes are vegetated by American beachgrass (*Ammophila breviligulata*) and poison ivy (*Rhus radicans*), which are important as stabilizers on the sand dunes and ridges.

Wildlife in the coastal region include whitetail deer, ruffed grouse, gray squirrel, chipmunk, woodcock, cottontail rabbit, pheasant, quail, red fox, skunk and opossum (NERBC, 1981). The creeks and marshes also support a large muskrat population.

The numerous bays, inlets, marshes and mudflats serve as important resting and feeding areas for migratory waterfowl and shorebirds in the Atlantic flyway. Waterfowl such as wood duck, mallard, black duck, Canada goose can be found in the tidal and inland wetlands, while Greater Scaup, Red-breasted Mergansers, Scooters and Goldeneye are found in the Sound during the winter. The intertidal flats support many species of shorebirds during the spring and fall migrations. Species include the snowy egret, common egret, great blue heron, little blue heron, black-crowned night heron, yellow-crowned night heron, American bittern, willets, plovers, and sandpipers. Raptors such as the osprey, red-tailed hawk and sparrow hawk are also found here. Various species of terns and gulls are the most common birds of the tidal flats.

The coastal area's streams and rivers support important anadromous fish species which include alewives, blueback herring, rainbow smelt, white perch, sea-run brown trout, American shad and striped bass (NERBC, 1981). Important commercial and recreational finfisheries in Long Island Sound include winter flounder, fluke, blackfish, bluefish, cod, blackback and yellowtail flounder, mackerel, weakfish and butterfish (U.S. Dept. of Commerce, 1980 and NERBC, 1981).

The most important commercial shellfish species are the eastern oyster (*Crassostrea virginica*) and American lobster (*Homarus americanus*). Other important shellfisheries include hard clams (*Mercenaria mercenaria*), bay scallops (*Aequipecten irradians*) and mussels (*Mytilus edulis*). Table 4 describes important shellfish concentration areas for each of the proposed sites in the study area.

TABLE 4

Shellfish Areas at Identified Sites in Study Area

Source: Connecticut Department of Environmental Protection, 1979

East Haven

- Eastern Oyster (*Crassostrea virginica*)--offshore from South End (Shell Beach, Morgan Point).

New Haven

- None in specific project site/study area.

West Haven

- Eastern Oyster (*Crassostrea virginica*)--mouth of Quinnipiac River in New Haven Harbor offshore from mouth of Cove River, and offshore from Old Field Creek.

Milford

- Eastern Oyster (*Crassostrea virginica*) and Hard Clam (*Mercenaria Mercenaria*) offshore from Bayview Beach.
- Hard clam (*Mercenaria mercenaria*) offshore from Fort Trumbull Beach, Gulf Beach, and south from Myrtle Beach to Milford Point.

Stratford

- Eastern Oyster (*Crassostrea virginica*)--offshore from Short Beach and Long Beach.

Fairfield

- Eastern Oyster (*Crassostrea virginica*)--offshore from Jennings Beach and Fairfield Beach.

Westport

- Eastern Oyster (*Crassostrea virginica*)--Compo Cove
- Hard clams (*Mercenaria mercenaria*) and eastern oyster (*Crassostrea virginica*)--offshore from Compo Beach, and mouth of Saugatuck River near Saugatuck Shores.

Threatened, Rare and Endangered Species - The U.S. Fish and Wildlife Service noted the presence of the Piping Plover (*Charadrius melodus*), a Federally listed threatened species which nests on Milford Point, Long Beach and Short Beach in Stratford, and Sandy Point in West Haven (USFWS, 1987). The Sandy Point area is also occupied by Least terns (*Sterna antillarum*), a species of state and regional interest. Five pairs of Piping Plovers nested at Sandy Point in 1987 and produced 8 young (USFWS, 1987). The Roseate tern, a Federally proposed endangered species, uses the Milford Point area during fall stopovers.

The National Marine Fisheries Service identified the presence of no endangered or threatened species which come under the jurisdiction of the Service in the project area (NMFS, 1987).

The Natural Resources Center of the CT Dept. of Environmental Protection reviewed the Natural Diversity Data Base maps and files for the presence of state species of special concern and critical habitats at each project site. A list of these species and critical habitats was provided for sites in the study area, and is shown in Table 5.

TABLE 5
SPECIES OF SPECIAL CONCERN

The species listed below are considered to be Species of Special Concern. The habitats mentioned have been identified as critical habitats and/or of high ecologic integrity (CT DEP, 1987).

Shell Beach, East Haven

Panicum amarum -Panic grass.

Diospyros virginianum -Persimmon

Sandy Point, New Haven

Charadrius melodus -Piping Plover (Federally listed as threatened)

Sterna antillarum -Least Tern

Eremophila alpestris -Horned Lark

Saline intertidal flats-important feeding area for shore birds

Coastal barrier beach

Cove River Area, West Haven

No known Species of Special Concern or critical habitat.

Milford Point Federal Coastal Wildlife Sanctuary

Charadrius melodus -Piping Plover (Federally listed as threatened)

Sterna antillarum -Least Tern

Eremophila alpestris -Horned Lark

Nycticorax violaceus -Yellow-crowned Night Heron

N. nycticorax -Black-crowned Night Heron

Progne subis -Purple Martin

Opuntia compressa -Eastern Prickly Pear

Panicum amarum -Panic grass.

Lordship Beach, Stratford

Aristida tuberculosa -Beach Needlegrass

Opuntia compressa -Prickly Pear Cactus

Short Beach, Stratford

Panicum amarum -Panic grass.

Charadrius melodus -Piping Plover (Federally listed as threatened)

Eremophila alpestris -Horned Lark

Sterna antillarum -Least Tern

Jennings Beach Area, Fairfield

Aristida tuberculosa -Beach Needlegrass

Sporobolus cryptandrus -Sand Drop-seed

Salt Marsh

Coastal Barrier Beach

Compo Cove Area, Westport

Salt Marsh

Major Heron Feeding Area

Historic and Archaeological Resources - There is extensive evidence of prehistoric occupation in the study communities. Numerous sites, mostly dating between 4,000 years ago to the mid-seventeenth century, are found along the Connecticut coast within the study communities (New Haven = 7; Milford = 11; Stratford = 5; Westport = 1). The majority of these known sites are found along estuaries, near tidal flats, or on small hills overlooking the adjacent coast. Of the sites contained in the state inventory, several are composed of large "shell middens", others contain native burials, and still others are listed as village sites.

When the first European settlers arrived to settle the Connecticut shore, they found many native Amerindian groups using the resources of the area. Groups such as the Pequot, Pequannock, and Wepawaug maintained cleared fields inland for the cultivation of corn and other crops, and harvested clams, oysters and other marine resources along the coast and estuarine rivers. The remains of a Amerindian fish weir were found near the mouth of the Housatonic River.

No Amerindian sites have been identified on the active shorefront within the study communities. Any sites that might have been located here have been subject to the erosional forces of the ocean and coastal storms since their abandonment, and are likely to be severely disturbed.

The early history of the Westport, Fairfield, Stratford, Milford, and New Haven coastal communities are similar. Most were incorporated as villages in the early seventeenth century, and were predominantly agriculturally oriented. The waterfront areas, were for the most part, not heavily developed until the late nineteenth and early twentieth century. Most towns, however, had a few small industries along the coast.

In Westport, a tidal mill was constructed at Compo Creek sometime after 1705. This mill's specialty was grinding kiln-dried corn for shipment to the West Indies. The foundation of the tidal gates at the junction of Compo Mill Beach and Old Mill Beach may be part of the old gristmill. Other tide mills were constructed at this time on Ash Creek in Fairfield and on the east side of Johnson's Creek in Stratford.

Salt Works were another enterprise which occurred along the coast in the eighteenth century. Large vats or salt pans were placed on the shore and filled in the spring. They were positioned to receive the full effect of the summer sun to increase evaporation. The Morris Cove Salt Works in East Haven were in operation until destroyed by fire during the British invasion of New Haven in 1779. In 1812, another attempt was made to manufacture salt in East Haven. These works were eventually moved to Merwin's Point in Milford, and operated until they were destroyed by a gale in 1821.

The Connecticut coastal towns played an active role in the Revolutionary War. Fairfield furnished supplies and men, and purported to be the center of "whale-boat warfare" for the coast. It was invaded and burned by the British in 1779. A monument on Compo Beach commemorates a battle fought at that point between British and American forces in 1777, and a colonial cemetery in Compo is supposed to contain Revolutionary War dead.

In the nineteenth century, oyster harvesting became an important and lucrative industry. Several structures present on 1868 (Beers) maps of New Haven and Milford were listed as "oyster houses", "oyster barns", and "oyster depots". By 1878, 200 acres of oyster grounds

were staked out near Pond Point, and 41 permits were issued that year in Milford for 2 acre oyster grants.

The construction of the electric street railway in the 1890's started a boom in shore property, and the summer resort business became one of the towns' most important enterprises. This area, with its proximity to Long Island Sound was now accessible, and became profitable land for real estate promoters.

Most towns had a particular locale which people flocked to in the summer to escape the city heat. In West Haven, soon after 1900, the "White City" amusement park was built near Savin Rock, a popular bathing area. Milford's beaches: Walnut Beach, Fort Trumbull Beach, Cedar Beach, etc., attracted crowds of summer residents. Fairfield, which, according to Beers had no structures on its coast in 1868, also became a popular location for residential use and development by the turn of the century.

An example of coastal development is The Schermerhorn House which was built in 1904 at Point Beach in Milford by the New York Protestant Episcopal City Mission Society. This institution was established as a fresh-air treatment facility for New York City's impoverished women and children.

Construction along the beaches greatly increased during the late 1920's. Most of the buildings erected were one family dwellings and populated chiefly by summer residents. In Milford, the influx of seasonal residents more than doubled the population during the summer of 1929.

In the early 1930's, building zone regulations were augmented to control the chaotic growth of the towns, and their summer colonies. During the Depression, construction declined and many seasonal residents began to occupy their cottages the entire year.

TIDAL FLOOD PROBLEM

Tidal flooding within the study area is caused primarily by hurricanes or extratropical storms. Hurricanes have been the most damaging, because their intensity has been a greater affect on tide levels and wave heights.

Hurricanes can be defined as tropical cyclones with a central barometric pressure of 29.0 inches or less and a maximum wind speed in excess of 75 miles per hour. In the northern hemisphere they consist of winds revolving in a counter-clockwise direction around a calm center or "eye". Their diameter can vary considerably, from as small as 50-75 miles across to over 500 miles wide. Winds at the outer edge are usually light and increase in intensity as they approach the center. Hurricanes that have had the most severe affect on the study area usually approach from the south after curving east of Florida and skirting the Middle Atlantic States. The tracks of recent major hurricanes are shown on Plate 3.

The two most damaging hurricanes experienced along Long Island Sound occurred during September 1938 and August 1954. Flood levels experienced during these events were used to prepare tidal flood profiles for areas along the shoreline. The study area base map and profiles are shown on Plates 4 and 5. A detailed description of these and other recent hurricanes is given in the following paragraphs. Further information on these and other events is contained in Appendix B.

Hurricane of September 21, 1938 - Tidal flooding from this hurricane was the greatest ever experienced in Long Island Sound. The center of the hurricane entered Connecticut perpendicular to the coast about 15 miles east of New Haven during mid-afternoon on September 21, 1938 and proceeded northwesterly at a forward speed of 50 to 60 miles per hour. The eye was clearly observed at New Haven. The lowest barometric pressure recorded during the storm was 28.04 inches at Hartford, Connecticut, with minimum pressures of 28.30 inches reported in Bridgeport and 28.11 in New Haven. The maximum wind velocity in New England was a gust of 186 miles per hour (mph) at the Blue Hills Observatory in Milton, Massachusetts, where a sustained five minute wind of 121 mph was also recorded. At locations along the southern coast, sustained five-minute velocities of the 38 to 82 mph were experienced. Hurricane tide occurred one to two hours before the predicted high tide. The effect of the hurricane was to cause extreme high tides throughout most of the Sound, with a tidal surge of about seven feet above the normal predicted tide at Bridgeport. Wave action accompanying the storm produced a devastating effect upon the shoreline, resulting in widespread damage. Wave heights ranged from ten feet at New London to 15 feet at New Haven and Bridgeport.

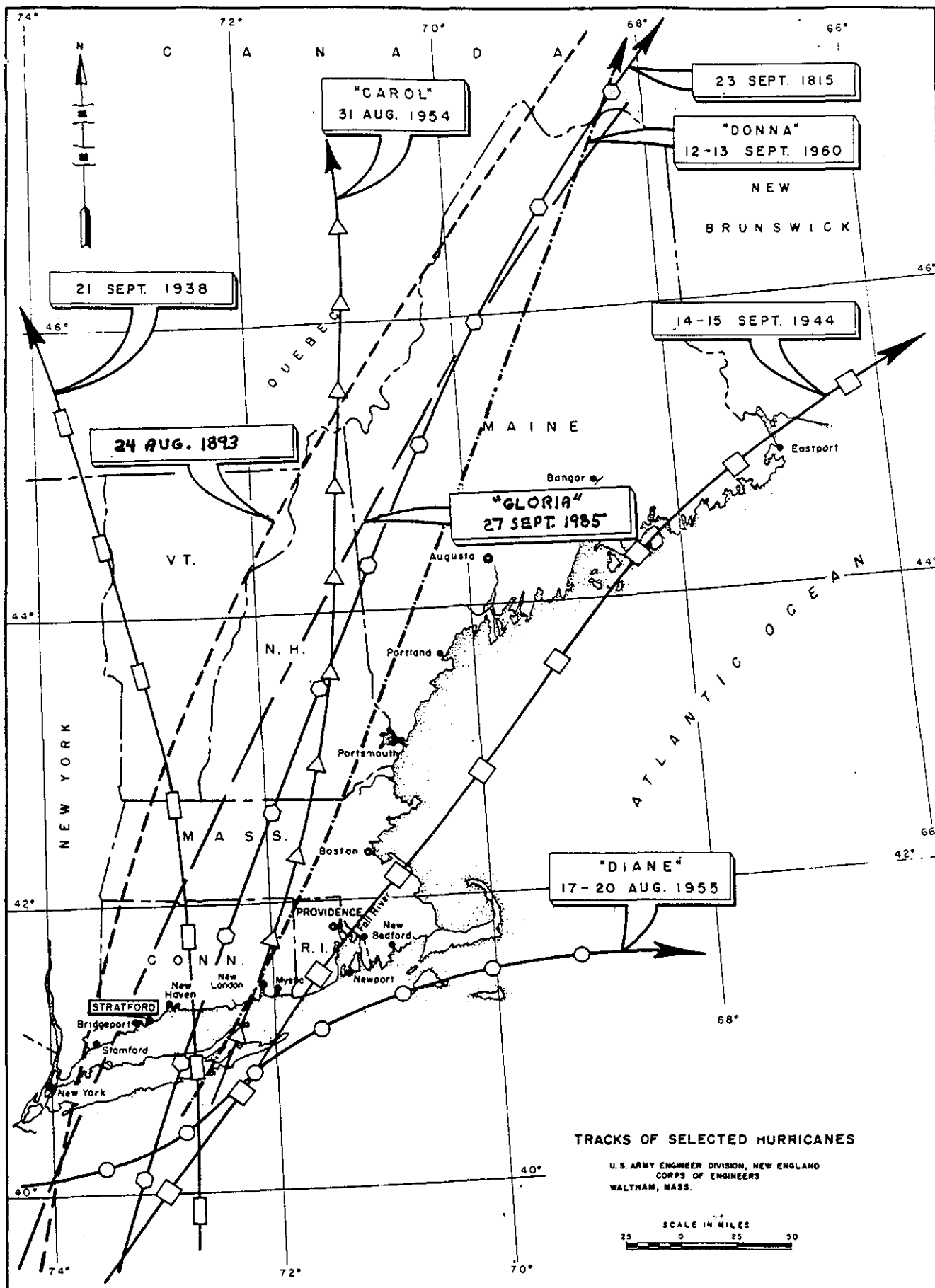
Hurricane of September 14, 1944 - In this event, the eye of the storm passed inland just west of Pt. Judith, Rhode Island and continued in a northeasterly direction at a forward speed of 30 to 35 mph veering out to sea at Boston, Mass. The hurricane tide arrived in the Sound at about mean tide at the eastern end and about two hours after predicted high tide at the western end, which resulted in moderately high ocean levels.

The maximum gust was an estimated 104 mph at Hartford, Connecticut. A one-minute wind of 99 mph and a five-minute velocity of 81 mph were recorded at New York City. The lowest pressure of 28.30 inches was recorded at Westerly, Rhode Island.

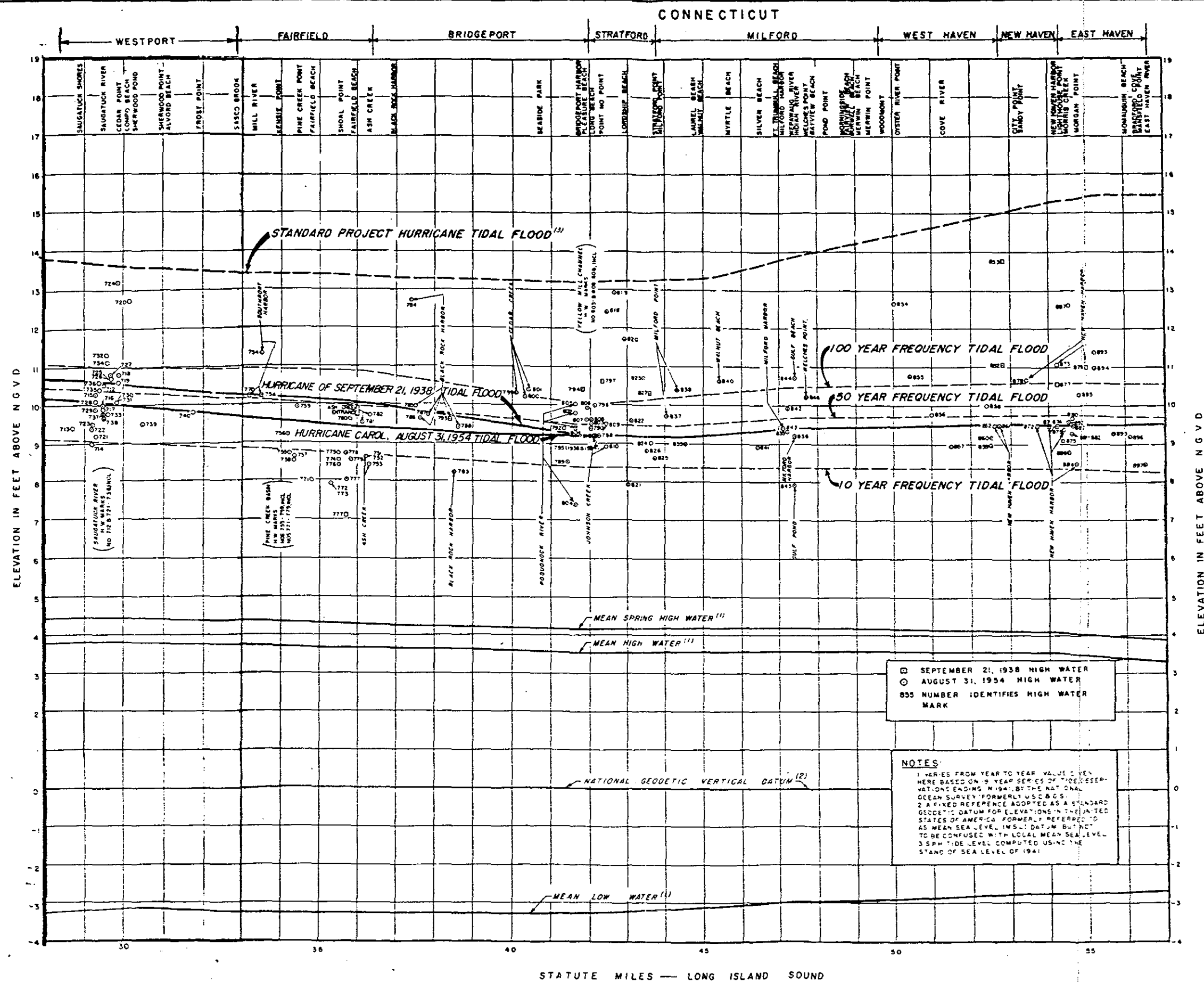
Hurricane of August 31, 1954 (Carol) - The second most damaging hurricane to strike southern New England occurred just 16 years after the record 1938 event. The center of this storm crossed the shoreline of Connecticut near New London with a forward speed of about 45 mph and then followed a general northerly path across New England. As the hurricane surge occurred at or near predicted normal high tide within the Sound, tide levels rose to near record heights. Tidal surges ranged from five to eight feet higher than predicted tides.

The wind attained a maximum gust of 135 mph and a five minute sustained velocity of 98 mph at Block Island, Rhode Island. Minimum pressures of 28.2 and 28.3 inches were recorded at Storrs and New London.

Damages from flooding of low shore areas occurred throughout Connecticut as a result of extremely high tides. Waves were particularly damaging east of the Connecticut River. Statewide damages occurred as a result of inundation of commercial and residential properties and coastal losses ranged from damage to fishing and pleasure craft, harbor facilities, shorefront residences and bathing beach establishments.







WEST CENTRAL CONNECTICUT
TIDAL FLOOD STUDY
PROFILE
SEPTEMBER 1987

Hurricane of September 27, 1985 (Gloria) - Hurricane Gloria made landfall in Westport, after crossing Long Island, at 1215 EST. The "eye" of the hurricane, then continued on its north-northeastward track, passing near Hartford before exiting the state at Suffield at about 1313 EST. Wind gusts of hurricane force ripped through the southern and central, as well as the eastern portion of the state, with the peak gust for the entire state recorded to 92 MPH at Bridgeport. The lowest sea level pressure was 28.50 inches, recorded at Bridgeport. Other peak wind gusts included 82 MPH at Hartford, 75 MPH at New Haven, and 66 MPH at Windsor Locks. Along the coast, up to 20,000 people were evacuated from their homes from Greenwich to Stonington and hundreds of small craft were torn from their moorings and damaged or sunk. Five docks were ripped up in Milford Harbor and about one hundred pleasure craft were torn from their moorings. However, the coastal flooding was at a minimum despite tides of 2 to 4 feet above normal, since Gloria reached the coast near low tide.

Tidal Flood Problem - Throughout history tidal floods produced by hurricanes and extratropical storms have caused loss of life, massive damage to public and private property and in some instances significant ecological destruction along the Connecticut shoreline. As described in the previous paragraphs, several severe hurricanes have struck the Connecticut coastline in the past 50 years with the most severe occurring on 21 September 1938. This storm caused tidal flooding along the Connecticut shore to elevations ranging from about 9.2 to 11.7 feet above mean sea level. In the next most severe hurricane, on 31 August 1954, flood stages approximated the 1938 level from the west limit of Stratford to the east limit of Madison. At other locations along the Sound, the 1954 stage was zero to 1.6 feet below the 1938 level.

In addition to high water levels, waves generated by wind, associated with severe storms can and have caused serious damage to the coastline. Although wave measurements or statistical wave data is very limited in the study area, waves generated by southwesterly to southeasterly winds pose the greatest threat to the study area. Since wave height is dependent upon wind speed and fetch distance, winds from southerly directions result in a much greater threat due to the relative long fetch available in Long Island Sound.

Past damages from hurricane tidal-flooding along the Connecticut coastline have been extensive. Surveys made after the 1938 and 1954 events reveal high property losses. A recurrence of the most recent severe hurricane, in August 1954, under 1987 conditions would cause losses of over 64 million dollars from tidal flooding in the eight study area communities, and a recurrence of the 1938 hurricane under 1987 conditions without any protection would result in losses from tidal flooding of over 97 million dollars.

Approximately 35,000 structures along the Connecticut shoreline which have been identified as flood prone of this number, about 12,000 are located in the study area. Connecticut has not experienced a major coastal flood for over 30 years, yet the damage potential associated with a coastal storm in study area is phenomenal, involving property destruction, business interruption, and possible loss of life. The most recent hurricane to the study area was Gloria in 1985. If the tidal surge associated with this Hurricane Gloria rather than at low tide the result tide levels would have been much higher. The municipalities of Connecticut must therefore develop and maintain a level of flood preparedness that is adequate to protect its citizens in the event of a major coastal flood.

In addition to the threat posed by coastal storms, the New England coastline is experiencing a phenomenon known as sea level rise. In the study area, this rise has been about one foot in the last century. Although there are many projections regarding future sea level changes, the Corps policy is one of concern rather than alarm. However, if the historic rate of rise were to continue, future flood levels would increase along with sea levels. A discussion of rising sea level is contained in Appendix B, page 34.

According to the Flood Vulnerability Assessments prepared by the Connecticut Department of Environmental Protection in 1983 and 1984, approximately 76% of the homeowners in Connecticut's 100-year flood zone feel that the risk of injury and/or property damage is an acceptable price to pay for living on the Connecticut coastline. About 63% of these homeowners have experienced flooding at their present location in the past. Some 52% of the homeowners could not afford to rebuild their homes in the event of a coastal storm, and only 36% have flood insurance. However, some homeowners have taken steps to protect their property. Approximately 35% have elevated their utilities above the 100-year flood levels, while another 18% would be willing to consider such a move. Also, about 13% have raised (elevated) their entire homes above the 100-year flood level.

Storm Impacts - Tidal floods produced by hurricanes and extratropical storms has been responsible for badly damaging or completely destroying residential, commercial, and industrial structures, roadways and recreational beaches and park areas in developed coastal areas. From a social standpoint this destruction has caused a number of problems which include: the relocation of entire families and in some instances, neighborhoods; unemployment due to the destruction or severe damage to industrial and commercial establishments; the loss of recreational facilities such as beaches and parks as well as boats and marina facilities; the disruption to the flow of traffic due to road damage; and public health problems due to water supply contamination or destruction of sewerage disposal systems.

Severe coastal storms also affect barrier beaches and salt water marsh land which provide feeding grounds and habitats for fish and wildlife in the area. Under hurricane conditions the waves often overtop these barrier beaches and carry a great deal of beach sand, sediment and debris with them which is deposited in the backshore marsh areas. This material is not only detrimental to the habitants and ecological processes in these marshlands, but builds up over the years reducing the amount of marshland that is available for fish and wildlife.

Existing Tidal Flood Control Projects - Presently there are no Corps of Engineers tidal flood control projects within the study area. There are, however, eight navigation projects, and 15 shore and bank protection projects located along the coast in the eight study area communities .

EXPECTED FUTURE CONDITIONS

Existing and future activities on coastal floodplain land in the study area is regulated and/or controlled by numerous laws, ordinances and policies. The National Flood Insurance Program, administered by the Federal Emergency Management Agency (FEMA) is currently in force for all communities. Under this program flood insurance zones and base flood elevation lines are established for each community. Subsidized flood insurance is then made available which is based on the Flood Hazard Factors of areas subject to flooding. To be eligible for Federal flood insurance, a community must adopt floodplain regulations to protect life and property from flooding, and control development in areas that are subject to flooding. All communities within the study area have adopted such regulations.

The State of Connecticut has also been very active in establishing regulations and programs to control development of floodplain lands. Floodplain management is presently being pursued in Connecticut under the following Acts:

- 1) Stream Channel Encroachment Act
- 2) The Inland Wetlands and Water Courses Act
- 3) The Tidal Wetlands Act
- 4) Flood Management for State Agencies Act
- 5) Structures and Dredging Act
- 6) The Diversion Act
- 7) Coastal Area Management Act

These Acts form the basis for the Connecticut Department of Environmental Protection policy on floodplain management. This policy involves both the careful regulation and control of development in floodplain areas, and the promotion of floodplain uses such as recreation and open space which are compatible with the flood threat.

Refinement of existing state and community preparedness plans is also expected to continue. With completion of the Corps' hurricane evacuation study in the early 1990's, a large amount of technical data concerning flooding will be available. This information, which will include data on population centers at risk, and evacuation on routes and concerns, will allow state and local officials to update their emergency response plans.

The impact of the above programs, regulations and policies will be to limit and control future development of floodplain lands, and to promote the wise use of the low-lying coastal environment. Even with these regulations, the pressure for coastal development has not subsided. The recent and on-going development and redevelopment of what is considered "prime" coastal areas is expected to continue. However, inasmuch as new construction or major reconstruction must have the first floor elevated above the 100 year flood height, future inundation damages are not expected to increase due to new construction.

PLANNING OBJECTIVES

Water resources planning undertaken by Federal agencies is directed by the Water Resources Council's Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. These principles provide the basis for Federal participation with river basin commissions, State agencies and other concerned groups in developing plans for the use of water and related land resources to meet short and long term needs. The Federal objective of such studies is to contribute to national economic development (NED), consistent with protecting the Nation's environment, pursuant to environmental statutes and applicable executive orders and Federal planning requirements. Plans will, therefore, be developed in the interest of achieving the general objectives of enhancing national economic development and protecting environmental quality. National economic development is enhanced by increasing the value of the output of goods and services, and by improving national economic efficiency.

Based on an assessment of the problems and needs of the study area, and the goals of the non-Federal sponsor, the study has concentrated on the following planning objectives:

- 1) Reduce potential tidal flood damage in the 8 study communities.
- 2) Preserve or enhance the environmental resources of coastal floodplain areas.

STUDY AND PLANNING CRITERIA

Recommendations to proceed to the next study stage (feasibility phase) were guided by two general criteria:

- 1) information be sufficiently detailed to determine that at least one potential solution will likely have Federal interest and be in accord with current policies and budgetary priorities; and
- 2) the potential solution be supported by the non-Federal sponsor, and consistent with their policies and statutes on coastal zone management, flood plain management and flood control. Since this study focused on flood damage reduction, Federal interest was established if a potential solution was economically justified and the non-Federal sponsor demonstrated support for further study.

SECTION III

ALTERNATIVE PLANS

MEASURES AVAILABLE TO ADDRESS THE FLOOD PROBLEM

To prevent or reduce flooding and associated damage, there are two basic types of protection available; structural and nonstructural. Structural and nonstructural measures differ in that structural measures affect the flood waters while nonstructural measures affect activities in the floodplain. Nonstructural solutions to flood problems are normally applied directly to each flood plain property or activity, in contrast to structural measures which normally affect the floodplain. Both types of flood control measures, or possible combinations, are evaluated to address the flood problem.

Structural Measures - Structural measures are characterized as those measures that prevent or reduce inundation of the floodplain. The following structural measures, either singularly or in combination with others, represent potential solutions to coastal flooding.

- Seawalls
- Dikes (to including the following)
 - (1) Dune restoration and beach nourishment
 - (2) road raising
- Bulkheads
- Tide gates or navigation gates
- Pumping facilities (used in conjunction with walls or dikes)

Nonstructural Measures - Nonstructural flood control measures are those measures which prevent or mitigate losses experienced by existing flood prone properties and activities, while allowing continued inundation of the floodplain. Applicable nonstructural measures are presented below:

Further information, including the advantages and disadvantages of each, is contained in Appendix D.

Floodproofing techniques - Floodproofing, by definition, is a body of techniques for preventing damages due to floods; requiring adjustments both to structures and to building contents. It involves keeping water out as well as reducing the effects of water entry. Such adjustments can be applied by an individual or as part of a collective action either when buildings are under construction or during remodeling or expansion of existing structures. They may be permanent or temporary.

Floodproofing, like other methods of preventing flood damages, has its limitations. It can generate a false sense of security and discourage the development of needed flood control and other actions. Indiscriminately used, it can tend to increase the uneconomical use of flood plains resulting from unregulated flood plain development.

A floodproofing program would normally warrant serious consideration in the following circumstances:

- Where floodproofing is the most economically feasible solution;
- Where flood control projects are not feasible due to environmental or other serious impacts;
- Where reduced flood risk could lead to more favorable flood insurance rates; and
- Where existing flood control projects provide only partial flood protection.

Although numerous measures exist, the following techniques apply to the study area:

- (1) Temporary or permanent closures for openings in existing structures
- (2) Raising existing structures
- (3) Rearranging or protecting damageable property within an existing structure
- (4) Relocation of existing structures and/or contents from a flood prone area

Flood forecast, warning and evacuation - This is a strategy to reduce flood losses by charting out a plan of action to respond to a flood threat. The strategy includes:

- A system for early recognition and evaluation of potential floods.
- Procedures for issuance and dissemination of a flood warning.
- Arrangements for temporary evacuation of people and property.
- Provisions for installation of temporary protective measures.
- A means to maintain vital services.
- A plan for postflood reoccupation and economic recovery of the flooded area.

Floodplain regulations - Through proper land use regulation, floodplains can be managed to insure that their use is compatible with the severity of a flood hazard. Several means of regulation are available, including zoning ordinances, subdivision regulations, and building and housing codes. Their purpose is to reduce losses by controlling the future use and changing the existing use of floodplain lands.

Some regulations covering the use of the flood plains are already in effect in the communities within the study area. Regulations may be relatively prohibitive or may allow construction, provided the new structures are floodproofed and/or elevated above a designated flood elevation.

Flood insurance - Flood insurance is not really a flood damage prevention measure as it doesn't reduce damages, rather it provides protection from financial loss suffered during a flood. The National Flood Insurance Program was created by Congress in an attempt to reduce, through more careful planning, the annual flood losses and to make flood insurance protection available to property owners. Prior to this program, the response to flood disasters was limited to the building of flood control works and providing disaster relief to flood victims.

Utilization of nonstructural measures usually requires a combination of measures to adequately protect activities in a floodplain. For example, raising existing structures above projected flood heights would not completely solve the flood problem. Residents or other occupants must be warned of expected flooding so that the area can be evacuated. In addition, further development of the floodplain should be regulated to prevent future flood damages. Appendix D contains a detailed description of the above measures, including the advantages and disadvantages of each.

DEVELOPMENT, EVALUATION AND SCREENING OF ALTERNATIVE PLANS

During the course of this reconnaissance study, numerous meetings were held with State of Connecticut officials and representatives of the eight study area communities. The purpose of these meetings was to identify potentially high damage areas and possible alternative flood damage reduction measures. Based on this evaluation of nearly the entire coastline from Saugatuck Shores in Westport to Mansfield Point in East Haven, over 30 sites were originally suggested for study.

In conducting the initial evaluation of these sites, all methods of reducing or eliminating potential flood damage were given consideration. The sites originally suggested for study and the various structural and nonstructural alternatives initially identified are shown on Table 6.

To determine which sites and alternatives warranted further study, an initial screening process was conducted. Factors considered during this process included the potential for flood damage, the possible environmental and social impacts, engineering feasibility, and public acceptability of identified alternatives. This preliminary screening process, which considered the views and desires of local interests, was conducted in conjunction with the Connecticut Department of Environmental Protection, Coastal Area Management (DEP/CAM) staff. The remaining sites and potentially feasible alternatives, shown on Table 7, were then analyzed to determine the costs and benefits of implementing various alternative plans.

Costs and benefits for these plans were developed based on providing protection from a 100-year tidal flood event. Annual costs were developed using a project economic life of 50 years and the current Federal interest rate of 8 5/8 percent. The results of these analyses are detailed in the following sections for each community.

Information contained in Federal Emergency Management Agency publications and cost figures obtained from local contractors were used to develop costs to raise structures. Based on this information, the average cost to elevate an existing structure was determined to be about \$28.00 per square foot of first floor area. This includes contingency costs and costs for engineering and design, and supervision and administration of construction.

TABLE 6
SITES AND ALTERNATIVES ORIGINALLY STUDIED

COMMUNITY/SITE	Dune Restoration & Beach Nourishment	Raise Roads	Tide Gates	Raise Bulkhead	Flood Warning & Evacuation	Floodproof Structures	Raise Structures	Relocate or Remove Structures	Dike	Seawall
East Haven										
Cosey Beach Ave	X	X		X		X	X	X		
West Silver Sands Beach	X	X		X		X	X	X		
Shell Beach	X	X		X		X	X	X		
New Haven										
Morris Creek		X		X	X	X		X		
Front St				X		X	X			X
West River				X	X					
West Haven										
West River/Front Ave				X	X					
Old Field Creek			X	X	X	X	X	X		
Cove River by Main St				X	X	X		X		
Oyster River/Rt 162		X	X	X	X	X		X		X
Milford										
Burwells Beach	X	X		X	X					
Point Beach	X			X		X				
Bayview Beach	X			X		X				
Gulf Pond/Indian River/Rt. 162				X	X	X				
Milford Harbor/Factory Lane				X		X				
Fort Trumbull/Silver Beaches	X			X		X				
Seaview Ave./Broadway	X			X		X				
Cedar Beach	X	X		X		X				
Stratford										
Broad St/Ferry Creek		X		X	X	X		X		
Main St/Airport		X								
Lordship/Beach Drive				X		X	X			
Surf Ave/Rt 113		X								
Long Beach				X		X				
Bridgeport										
Pleasure Beach				X	X					
Seaside Park/Cedar Creek		X		X	X			X		
Fairfield										
Ash Creek				X		X		X		
Jennings Beach	X			X		X		X		
Fairfield Beach/Road	X	X		X		X		X		
Pine Creek			X	X		X		X		
Westport										
Compo Mill Beach				X		X	X			
Old Mill Beach				X		X				
Compo Beach				X		X	X			
Saugatuck Shores		X		X	X					

TABLE 7
FINAL SITES AND ALTERNATIVES STUDIED

COMMUNITY/SITE	Dune Restoration & Beach Nourishment	Raise Roads	Flood Warning & Evacuation	Raise Structures	Dike
East Haven					
Cosey Beach Ave			X	X	
West Silver Sands Beach			X	X	
Shell Beach			X	X	
New Haven					
Front St			X	X	
West Haven					
Old Field Creek	X	X	X	X	X
Cove River by Main St			X	X	
Oyster River/Rt 162			X	X	
Milford					
Burwells Beach	X		X	X	
Point Beach	X		X	X	
Bayview Beach	X		X	X	
Fort Trumbull/Silver Beaches	X		X	X	
Seaview Ave./Broadway	X		X	X	
Cedar Beach/Milford Point			X	X	
Stratford					
Broad St/Ferry Creek		X	X	X	
Lordship/Beach Drive			X	X	
Long Beach			X	X	
Bridgeport					
Fairfield					
Jennings Beach/Ash Creek	X		X	X	
Fairfield Beach/Pine Creek	X		X	X	X
Westport					
Compo Cove (Compo Mill & Old Mill Beaches)			X	X	
Compo Beach			X	X	X
Saugatuck Shores			X	X	

Benefits attributable to protective works considered in this study were developed by conducting damage surveys of the 21 sites shown on Table 7. Damage evaluation teams visited each site, noted the physical characteristics and location of properties and conducted random interviews with local residents. This information, along with that obtained at local assessors' offices, formed the basis for calculating damages. To obtain expected damage figures, this information was then correlated with data concerning the frequency and depth of flooding. The annual flood reduction benefits attributable to a plan are then measured by subtracting annual damages remaining with a plan from total annual damages expected under current conditions. Appendix C details this procedure and provides additional data concerning the economic analysis of the study sites.

Costs for structural plans considered in this report were based on actual costs for similar work which were adjusted to reflect current costs in the Connecticut area. Of particular note is the cost of sand necessary for dune and beach nourishment projects. An analysis conducted by this office in conjunction with our evaluation of an erosion problem at Savin Rock Beach, West Haven (See Page 4 - Corps' Support-for-Others Program) determined that sand must be brought in from other areas as local suppliers are unable to supply the large quantities of sand required. Considering the purchase cost, and costs of transportation and placement, the final cost per cubic yard of sand was in the \$20.00 to \$25.00 range. An average cost of \$22.00 per cubic yard was used to develop costs in this report. Costs for engineering and design, and supervision and administration of construction must be added to develop total project cost.

EAST HAVEN

Sites and Alternatives Studied - Three sites covering most of the relatively short East Haven coastline were identified for study, Cosey Beach Avenue, West Silver Sands Beach and Shell Beach. All three are mostly residential areas with a mix of summer cottages, permanent homes and new condominium developments. Plate 6 shows the location of these sites. Many homes are located on the barrier beach. Much of the present flooding is due to poor interior drainage and some roads are frequently inundated. Many residents in this area have flood insurance. All new development in East Haven, as well as in all other study communities, is required to have first floor elevations above the 100-year flood frequency level. These locally enforced regulations are required by the Federal Emergency Management Agency (FEMA) for participation in the regular flood insurance program.

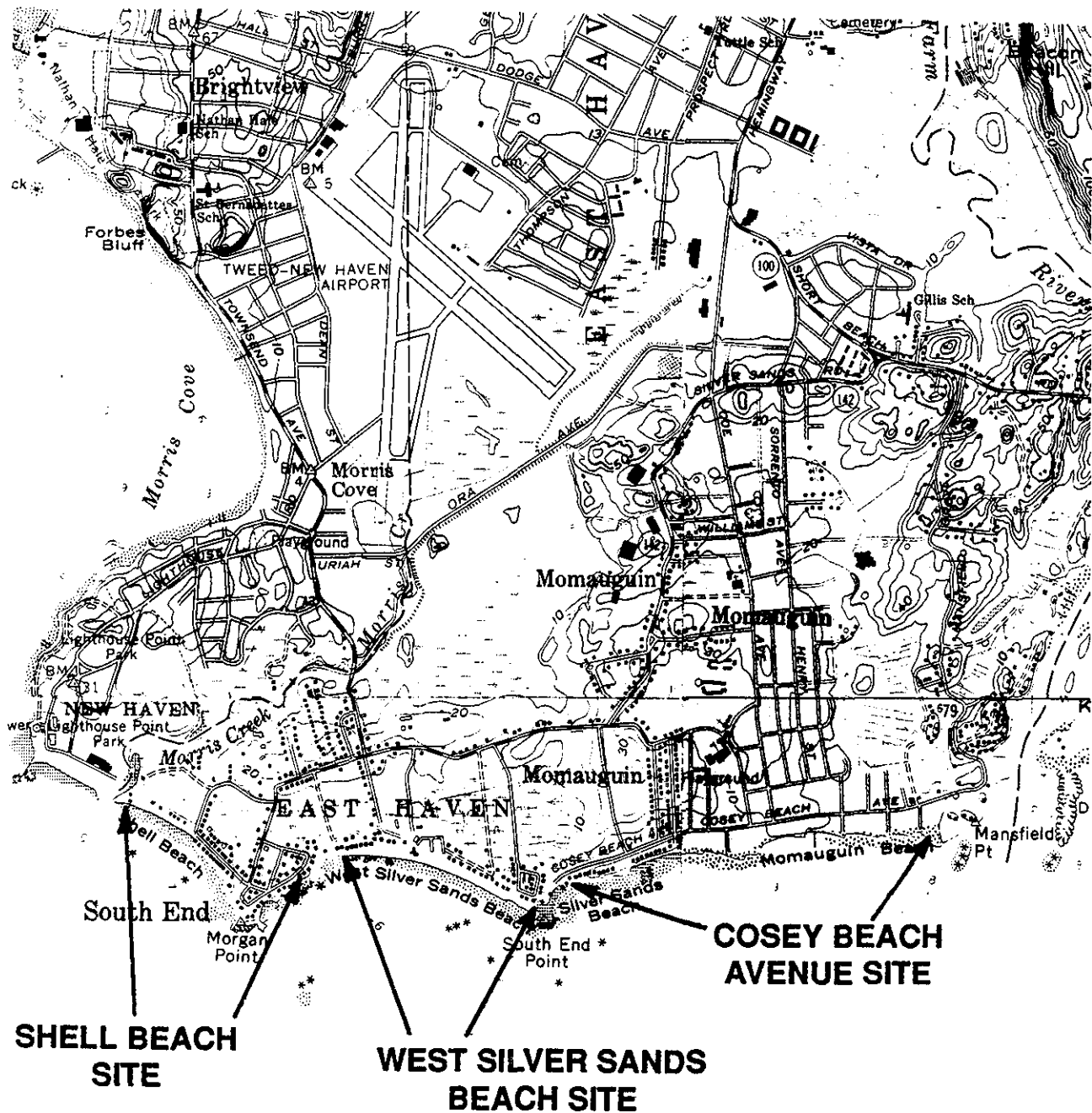
Alternatives originally considered for all three sites included low dikes, beach nourishment and sand dune restoration, raising roads, flood warning and evacuation, raising structures, and relocation or removal of structures. Only flood warning and evacuation, and raising structures were determined to warrant further study. The other alternatives would not provide adequate protection, were far too expensive, or were politically and environmentally unacceptable.

Environmental Considerations - The coastline along the East Haven site is characterized by sandy/pebbly beaches with a mixture of year-round and summer homes lining the shorefront along West Silver Sands Beach and Shell Beach. Salt marshes extend landward from the cottages, with *Spartina alterniflora* and *Spartina patens* the dominant vegetative species. Disturbance (filling and restriction of salt water flushing) of these marsh areas is indicated by the presence of *Phragmites australis* along some of the marsh fringes. Mute swans were observed offshore from Mansfield Point. New condominiums have been built at the end of Cosey Beach Ave., adjacent to Farm River Creek, as well as along Shell Beach. Both developments have resulted in some disturbance to adjacent salt marshes by filling activities. There would be no significant environmental concerns associated with the nonstructural plans of raising structures and flood warning and evacuation.

Economic Analysis - The following tabulation presents the costs, benefits and resultant benefit to cost ratio of raising structures at each site.

	Number of Structures	First Cost	Annual Cost	Annual Benefits	Benefit Cost Ratio	Net Benefits
Cosey Beach Ave.	524	\$14,672,000	\$1,286,000	\$85,100	0.07	Negative
W. Silver Sands Beach	68	\$ 1,904,000	\$ 166,900	\$10,600	0.06	Negative
Shell Beach	126	\$ 3,528,000	\$ 309,200	\$23,300	0.08	Negative

As shown in the above table, the cost of raising structures far exceeds flood control benefits. Therefore, there are no economically feasible alternatives at these three coastal sites. It is recommended, however, that a local or regional flood warning and evacuation plan be implemented to prevent possible loss of life and help reduce flood losses.



STUDY SITES
EAST HAVEN, CT
PLATE 6

NEW HAVEN

Sites and Alternatives Studied - Three sites were initially identified for study. Two of these sites - Morris Creek and West River were deleted early in the study process, while the Front Street site north of the Grand Avenue bridge was given further consideration. The location of Front Street is indicated on Plate 7.

The Morris Creek site has been the subject of several previous studies by the City of New Haven and State of Connecticut involving a dike and creek relocation plan. Due to the availability of these existing studies, the Connecticut Department of Environmental Protection requested that we delete this site from further consideration.

The West River site was determined to have an insignificant Federal interest with minimal damage potential from flooding of wetlands, some of which is presently controlled by a tide gate.

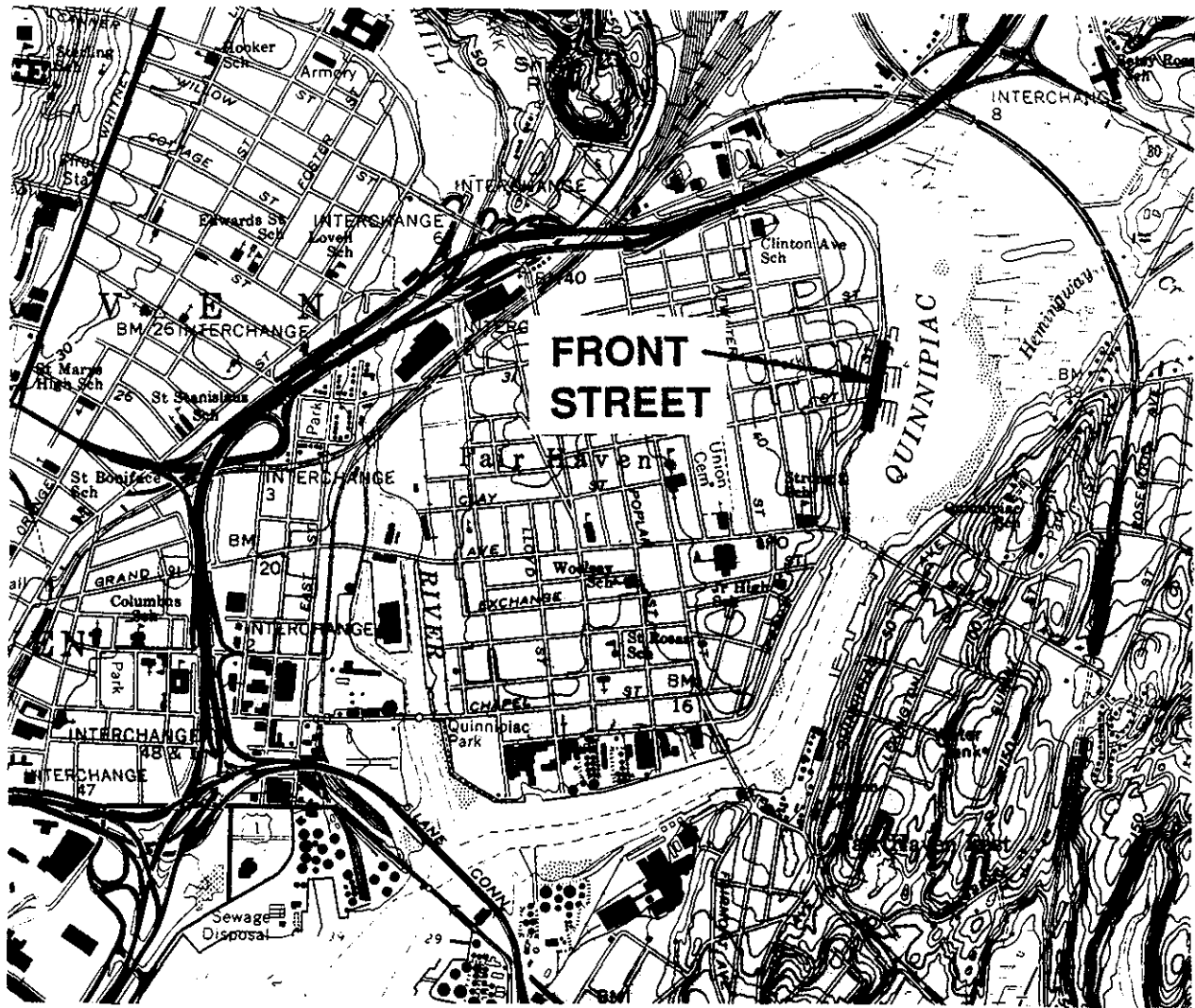
The Front Street site consists of a few homes, several commercial establishments and a new condominium development. The condominiums are being constructed with first floor elevations above the FEMA 100-year flood elevation. Of the flood damage reduction alternatives considered for this area, construction of a seawall and relocation of properties were eliminated during the initial review process due to high costs, and potential environmental and other impacts. Raising structures, and flood warning and evacuation were considered further.

Environmental Considerations - The Front St. site is located along the Quinnipiac River. This site is made up of older residential homes along the riverfront, with scattered small patches of *Spartina alterniflora* between the piers and docks along the shoreline. There would be no significant environmental concerns associated with the nonstructural plans.

Economic Analysis - The costs and associated benefits to raising structures along Front Street are presented below:

	Number of Structures	First Cost	Annual Cost	Annual Benefits	Benefit Cost Ratio	Net Benefits
Front Street	36	\$ 1,008,000	\$ 88,400	\$28,000	0.32	Negative

Based on a benefit to cost ratio of 0.32, further study of raising homes along Front Street would not be economically justified. An early warning and evacuation plan should, however, be considered for this area.



STUDY SITE
NEW HAVEN, CT
PLATE 7

WEST HAVEN

Sites and Alternatives Studied - Four sites in West Haven were initially identified for study. These sites were: West River/Front Avenue, Old Field Creek, Cove River by Main Street, and Oyster River/Route 162.

The West River/Front Avenue site was determined to have an insignificant Federal interest due to minimal damage potential. Only a very small section of Front Avenue is subjected to tidal flooding from the West River.

The Old Field creek site consists of a residential neighborhood which is subjected to flooding from a tidal wetland and Old Field Creek. As shown on Plate 8, the neighborhood surrounds the wetland and creek. To provide protection to this area, a total of three structural alternatives and one nonstructural alternative were investigated. They were: (1) construction of a sand dune and berm on the seaside of Beach Street, (2) raising Blohm Street, (3) construction of low dikes along the perimeter of the Old Field Creek wetland, and (4) raising structures. Early warning and evacuation was retained as a consideration in all plans. These alternatives are presented in further detail below.

Dune and berm construction along Beach Street would consist of extending a shore protection project currently under consideration for the Savin Rock Beach area. Investigation of this plan was requested by the West Haven City Engineer. All plans under consideration for the Savin Rock Beach area include placement of a sand beach berm and dune for shore protection. Since the Savin Rock Beach proposals end at one limit of flooding in the Old Field Creek area (Morse Street), extending this dune past the Old Field Creek area to prevent coastal flooding is a technically feasible solution. To develop the cost of this alternative, a dune with the same configuration as the Savin Rock Beach area was investigated. This sand dune would have a top width of 20 feet, a base width of 50 feet and a crest elevation of 13.21 feet NGVD (16.0 feet MLW). The dune would be stabilized by planting dune grass. The berm would have a width of 50 feet at an elevation of 8.21 feet NGVD (11.0 feet MLW) and be fronted by a 1 vertical on 8 horizontal (1:8) sloped beach face. If properly maintained the berm and dune combination should easily protect against a 25 year event. The limits of this plan are shown on Plate 9.

The dune project, which would begin at Morse Avenue and terminate at a Town park near the intersection of Beach Street and Second Avenue, would have a total length of about 2900 feet. Although the project must cross Beach Street near Second Avenue, a traditional stoplog or gate structure was not proposed since the protection would be built from natural materials compatible with the site. With a road elevation of about 8.5 feet NGVD, this gap of 50-60 feet could be closed during a flood event by dumping sand or gravel on the roadway. This type of closure should be effective since the height of fill would be less than five (5) feet and this area should not be subject to wave action as it runs nearly perpendicular to the shoreline.

The Raising Blohm Street alternative would consist of raising the road surface to an elevation of 13.6 feet NGVD to provide protection against a 100 year flood event. The road raising would begin at a point 250 feet southwest of the Noble Street and Morse Avenue intersection, run along Morse Avenue to Blohm Street and then along Blohm Street to a point near Second Avenue. The total length of the project would be about 2350 feet. In addition to road raising, the major project features would include a new gated culvert at Old Field Creek, utility relocations, and driveway modifications.

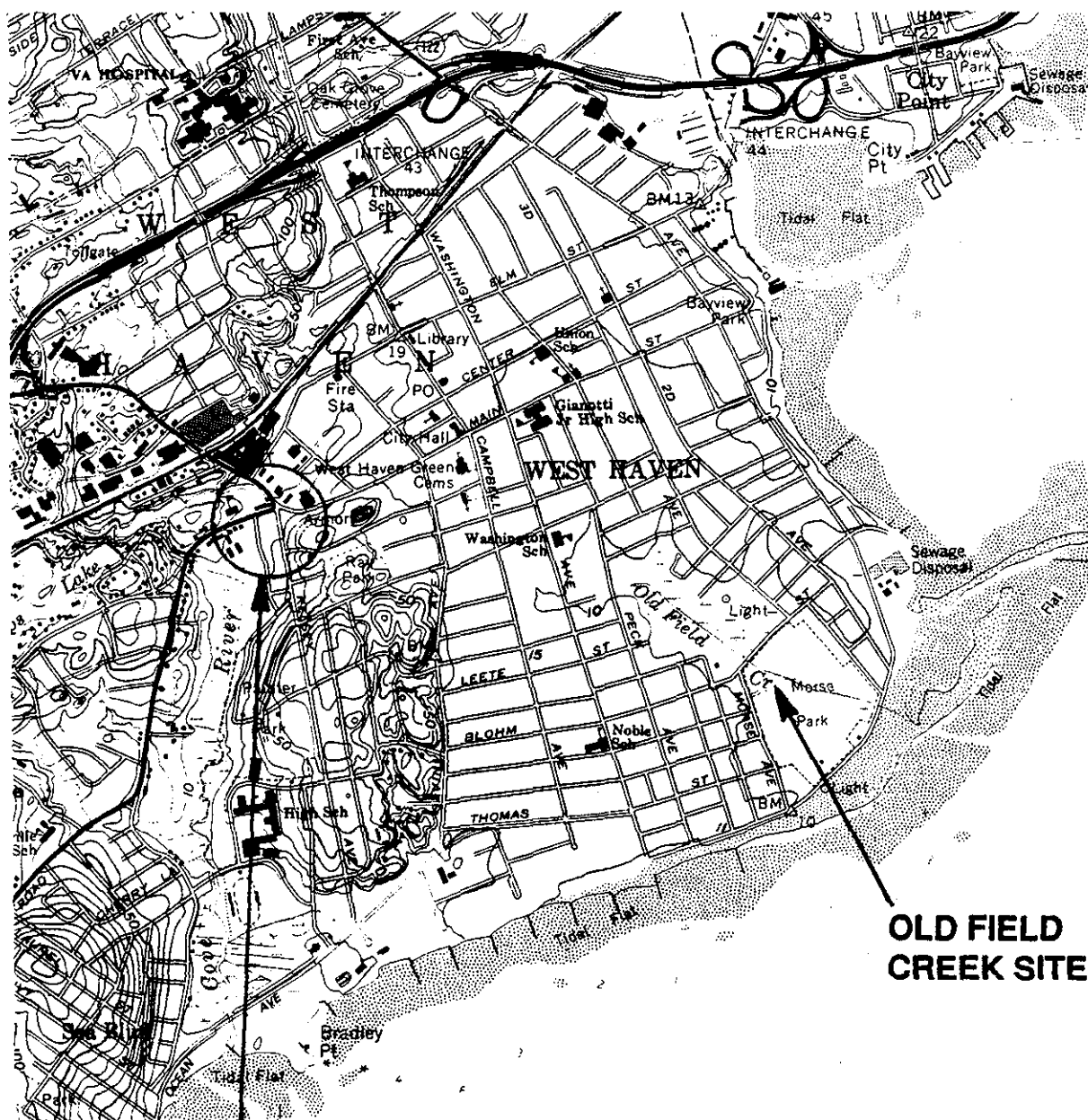
In analyzing the possibility of constructing low dikes along Old Field Creek, two possible diking plans were identified. Plate 10 shows the location of these plans. Both plans have a top elevation of 13.6 feet NGVD and would provide protection from a 100 year flood event.

The first plan (Dike Plan 1), which would protect the entire flood prone area, included 8900 feet of dike, 800 feet of road raising and two flood gates. The dike would extend around the entire wetland from an area near the Beach Street and Morse Avenue intersection to a point near the intersection of the Third Avenue Extension and Beach Street. Road raising would be required along sections of Second Avenue and Beach Street, and flood gates would be necessary to close two openings on Blohm Street.

The second plan is shorter in length, but protects the majority of flood prone area. It included 6450 feet of dike, raising 700 feet of roadway and two flood gates along Blohm Street. The dike would begin at a point near the Noble Street and Morse Avenue intersection, extend around the wetland, and terminate near the southwest end of Division Street. Road raising along sections of Noble and Division Streets would also be required to tie the dike into high ground.

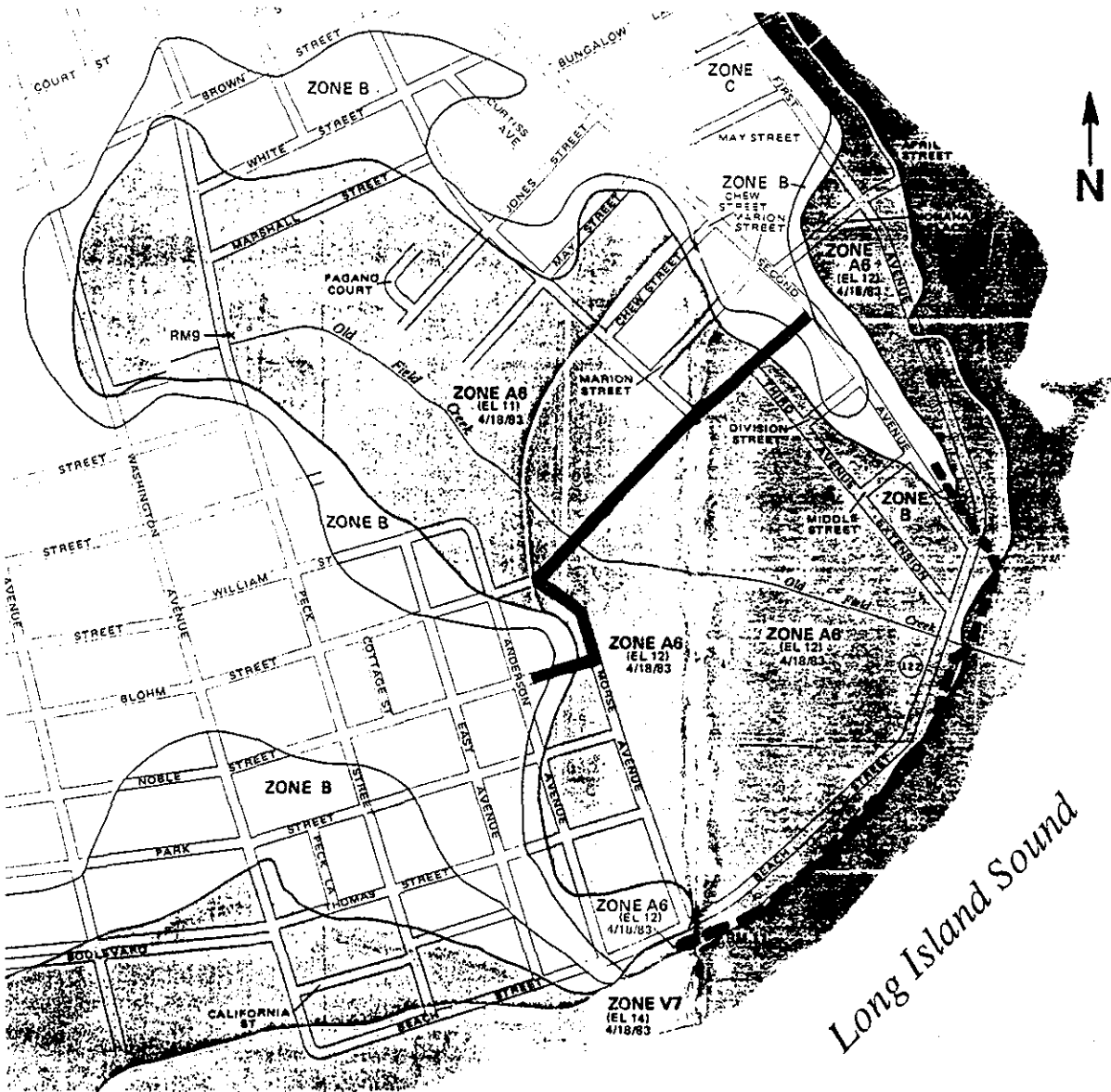
The next site investigated was Cove River by Main Street (see Plate 8). This site contains homes, a few commercial establishments and apartment buildings threatened by flooding from the Cove River as the flow backs up during coastal storm events and high tides. Alternatives warranting further study in this area include raising homes where necessary, as well as flood warning and evacuation.

The Oyster River and Route 162 site, shown on Plate 11, consists of several homes and commercial establishments. Alternatives originally considered for this area included dikes, a seawall, a tide gate, road raising, floodproofing, raising structures, and flood warning and evacuation. The dike, tide gate, seawall, floodproofing structures, and road raising plans were eliminated due to high cost, lack of effectiveness, and as being politically and environmentally unacceptable. Raising homes, and floodwarning and evacuation were accepted for further study.



COVE RIVER/MAIN STREET SITE

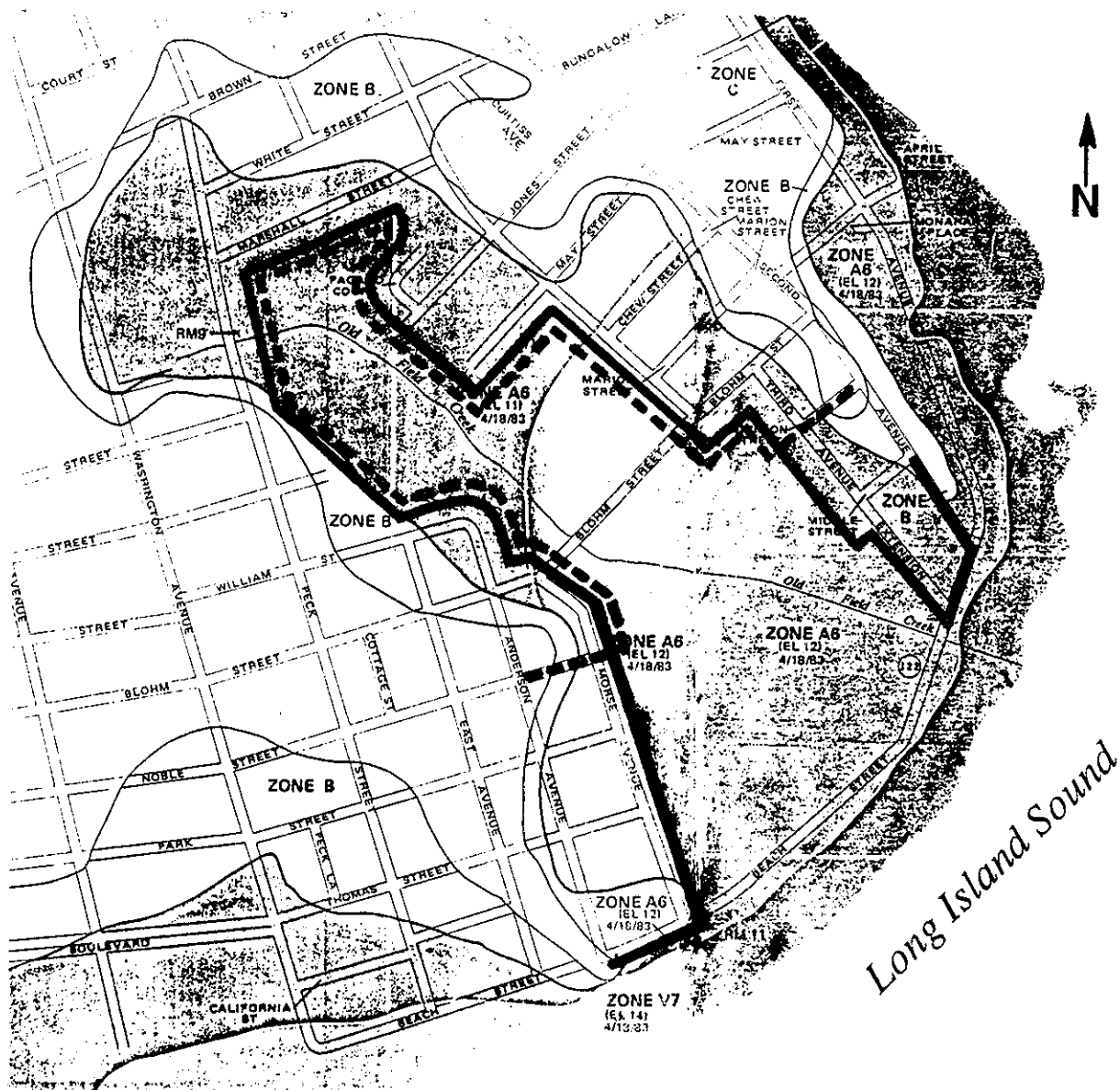
**STUDY SITES
WEST HAVEN, CT
PLATE 8**



Legend

- Road Raising Plan
- - -** Dune and Berm Plan

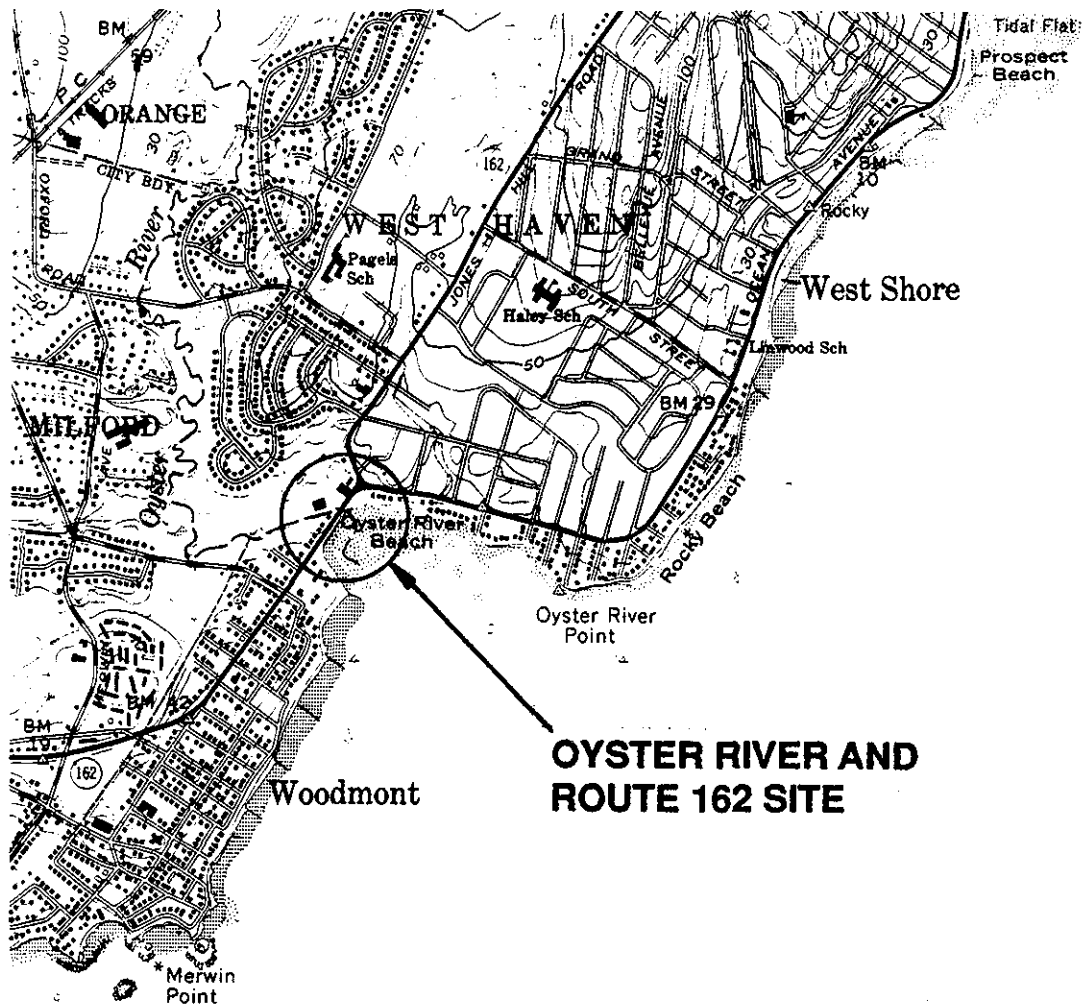
**ALTERNATIVE PLANS
OLD FIELD CREEK
WEST HAVEN, CT
PLATE 9**



Legend

- Dike Plan 1
- - - Dike Plan 2

ALTERNATIVE DIKE PLANS OLD FIELD CREEK WEST HAVEN, CT PLATE 10



STUDY SITE
WEST HAVEN, CT
PLATE 11

Environmental Considerations - Old Field Creek is surrounded by a *Phragmites* marsh which immediately borders the backyards of the homes under study at this site. The creek runs underneath Beach St., between wooden training walls at the sandy beach, then into Long Island Sound. The beach area is presently being rehabilitated by the City of West Haven with a new walkway/bikepath along Beach St. A piping plover nesting area is located at the base of Sand Point, southeast of the site, and has been fenced off from the rest of the beach area. The Sandy Point area is also occupied by Least terns, a species of state and regional interest, and other shorebirds (USFWS, 1987). Five pairs of piping plovers nested at the Sandy Point location in 1987 and produced 8 young (USFWS, 1987). Horseshoe crabs, *Ulva* (sea lettuce), and shell fragments were observed on the beach (September 1987). The Old Field Creek wetland was noted by the State as a possible site for restoration of the salt marsh with the installation of a self-regulating tide gate.

A dike plan for the area in back of the homes along Old Field Creek would result in encroachment into the north, east and west sides of the marsh. Potential impacts associated with a dike plan at Old Field Creek include encroachment and modification of natural run-off patterns at the marsh. The piping plover at Sandy Point and least terns would most likely be disturbed by work along Beach Street and construction of the southeastern portion of the dike (USFWS, 1987). The wetland impacts associated with diking could conflict with State of Connecticut Coastal Area Management policies.

Cove River flows through the downtown area of West Haven. In the area under study near Main Street, an apartment building is located immediately adjacent to the creek with a small walkway constructed over the creek to provide access to the building from the parking lot. The streambank is characterized by the presence of jewelweed (*Impatiens capensis*) and various weeds and small shrubs indicative of a disturbed area. Further downstream, the creek is bordered almost totally with *Phragmites*.

On the shoreward side of Rt. 162 at the mouth of Oyster River there are extensive tidal flats, and a rocky beach with healthy stands of *Spartina alterniflora*. Construction of dikes, seawalls or tide gates would result in encroachment on the marsh and tidal flat areas, and would not be consistent with coastal zone policies.

There would be no environmental concerns associated with nonstructural solutions at these sites in West Haven.

Economic Analysis - costs and attributable benefits for structural and plans evaluated in West Haven are presented in the following table.

	Number of Structures	First Cost	Annual Cost	Annual Benefits	Benefit Cost Ratio	Net Benefits
Old Field Creek						
1) Dune & Beach Nourishment		\$ 1,430,000	\$ 141,200	\$ 8,800	0.06	Negative
2) Raising Blohm Street		\$ 710,000	\$62,200	\$41,800	0.67	Negative
3) Dike Plan 1		\$ 2,580,000	\$226,100	\$44,200	0.20	Negative
4) Dike Plan 2		\$ 1,980,000	\$173,500	\$41,800	0.24	Negative
5) Raising Structures	125	\$ 3,500,000	\$306,800	\$44,200	0.14	Negative
Cove River/Main Street						
Raising Structures	55	\$ 1,540,000	\$ 135,000	\$38,600	0.29	Negative
Oyster River/Rt. 162						
Raising Structures	99	\$ 1,092,000	\$ 95,700	\$13,500	0.14	Negative

As shown in the above analysis, none of the plans evaluated for West Haven were economically justified. Based on the potential for flood damage in these areas, implementation of a flood warning and evacuation plan is suggested.

MILFORD

Sites and Alternatives Studied - Eight sites covering most of the coastline of Milford were identified for study. These eight sites were: Burwells Beach, Point beach, Bayview Beach, Gulf Pond/Indian River/Rt. 162, Milford Harbor/Factory Lane, Fort Trumbull/Silver Beaches, Seaview Ave./Broadway, and Cedar Beach.

Two sites, Gulf Pond/Indian River/Rt. 162 and Milford/Factory Lane, were determined to have insignificant Federal interest due to a lack of potential benefits. These are only a few homes and commercial buildings subject to minor flooding in the two areas.

Alternatives originally considered for the six remaining sites included dune restoration/construction and beach nourishment, raising structures, flood warning and evacuation, and in the case of Cedar beach, road raising and relocation. Road raising was determined to have no significant impact on flood damage reduction, and relocation was considered impractical and too expensive, as well as politically unacceptable. Sand dune restoration and beach nourishment at Cedar Beach was also not feasible because of high costs and the potentially severe adverse environmental impacts. Dune restoration/construction and beach nourishment plans were developed in some detail for the other five sites. These plans are presented in the following paragraphs. Further study of raising structures and flood warning and evacuation was conducted for all six sites. Dune construction plans for all five sites would have the same height and basic configuration. The top elevation of the dune would be at elevation 17.0 feet NGVD. The dune would be stabilized by planting dune grass. A 50 feet wide berm would be located on the seaside of the dune at elevation 11.0 feet NGVD to protect the dune against excessive wave action. This berm would be fronted by a sloped beach face of essentially the same slope as the existing beach.

The approximate length and limits of these dune projects are presented as follows:

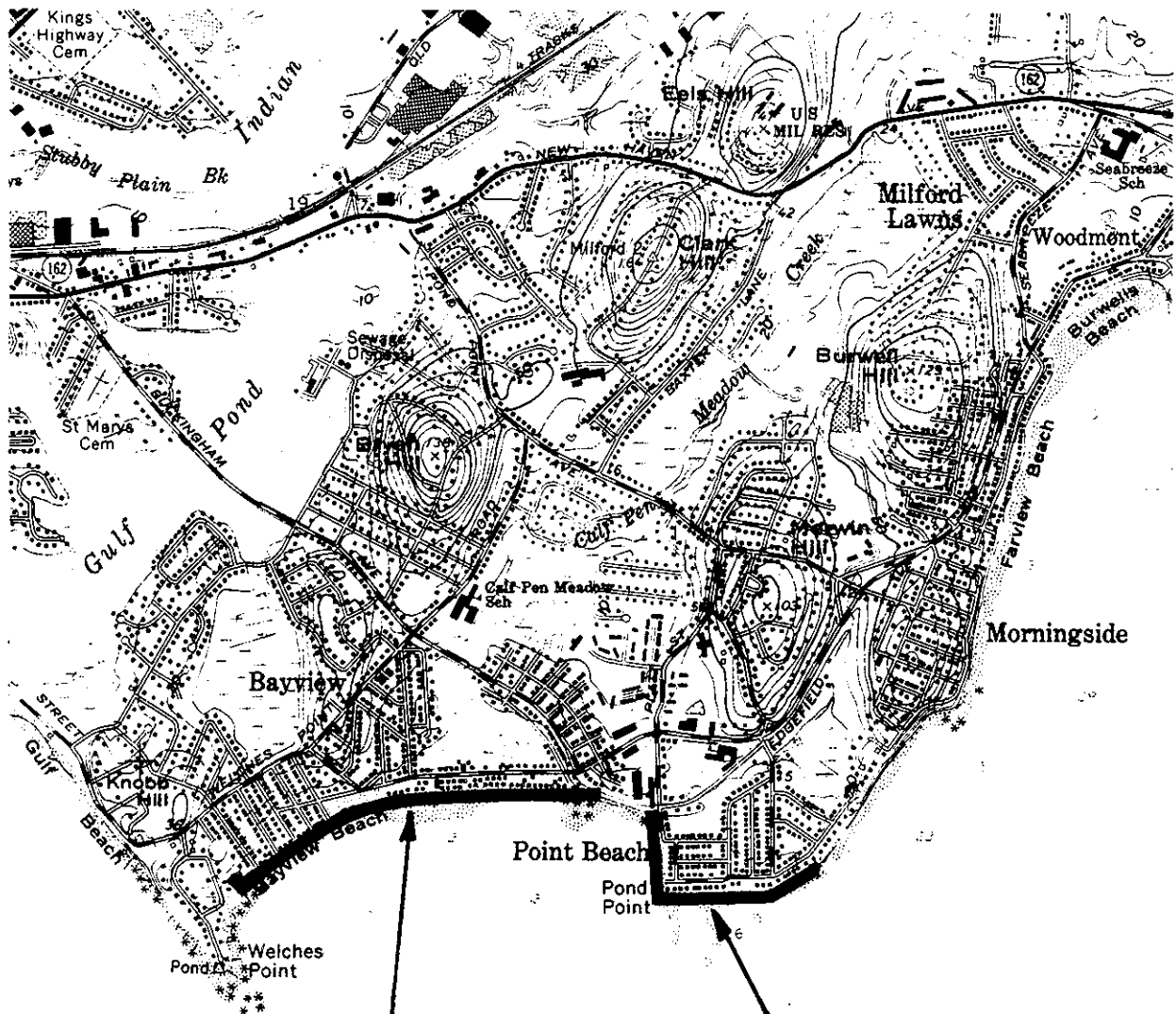
Burwells Beach - The dune would be approximately 3,300 feet long, extending from Paris Street to Poli Terrace. To complete the protective loop, two walls or dikes, each about 200 feet long, would be required at each end of the dune. Plate 12 indicates the location of this dune alternative.

Point Beach - A dune approximately 3,000 feet long, tying to high ground at each end, would protect this area (see Plate 13).

Bayview Beach - Protecting this area would require a dune about 4,400 feet long and tide gate at Calf River. The dune would extend to high ground at each end (see Plate 13).

Fort Trumbull/Silver Beaches - Approximately 4,500 feet of dune would be necessary to prevent flooding of this area. In addition, a dike about 1,700 feet in length along the service road and a street gate at Samuel Smith Road would be required to complete the loop of protection. The approximate location of this dune is shown on Plate 14.

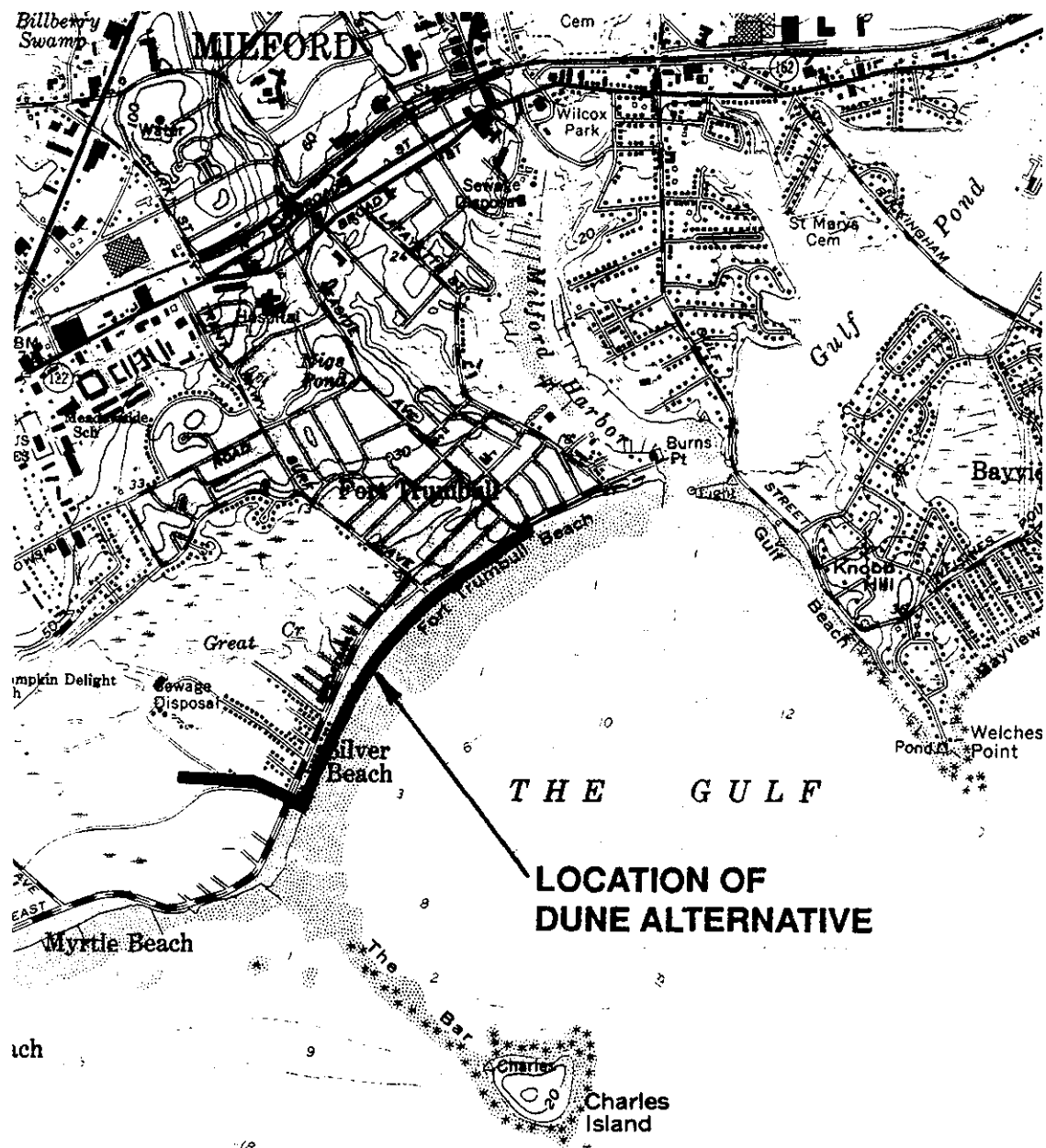
Seaview Avenue/Broadway - A dune about 4,700 feet long, and walls or dikes about 800 feet in length at each end would provide protection in this area (see Plate 15).



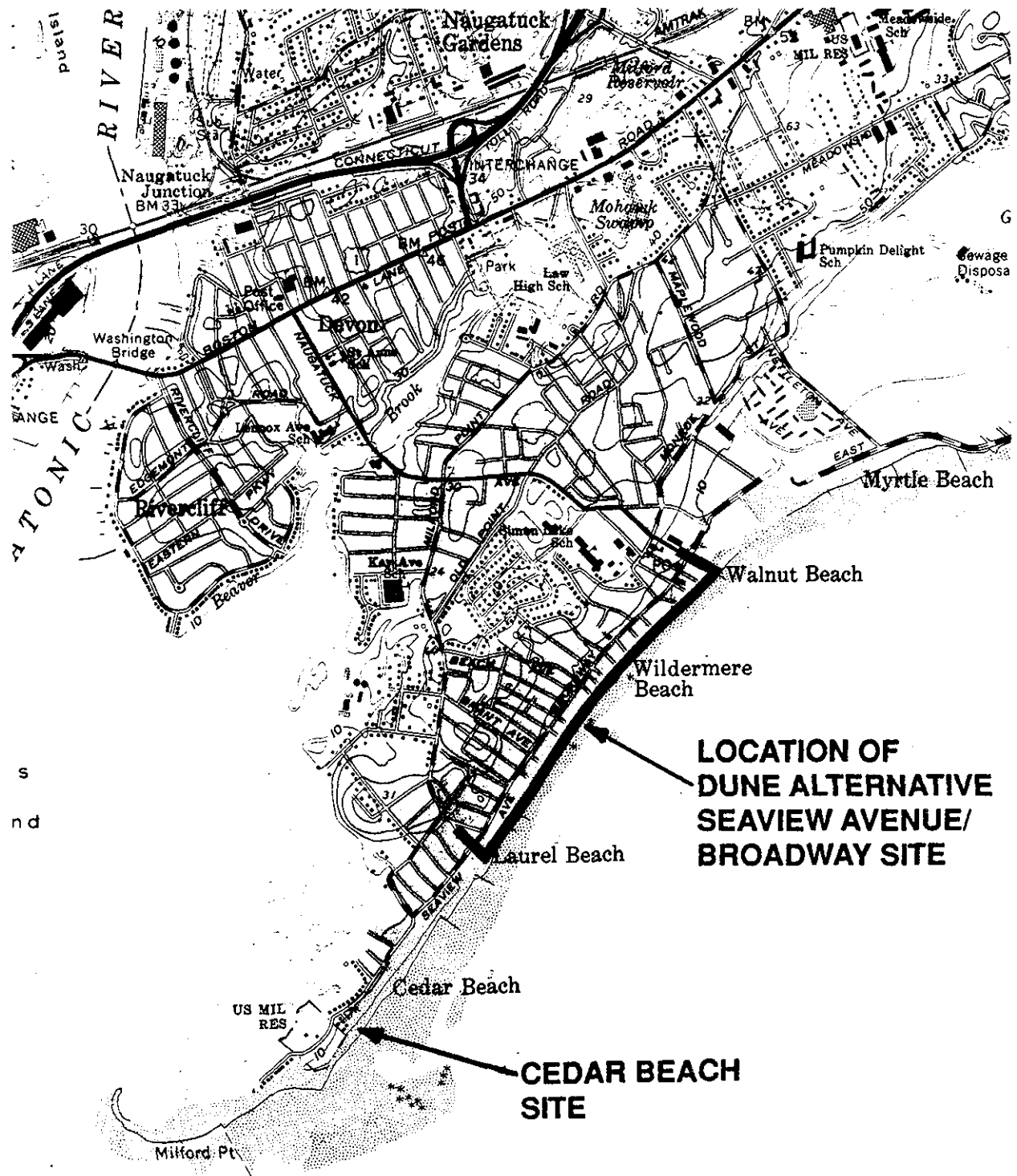
**LOCATION OF
DUNE ALTERNATIVE
BAYVIEW BEACH SITE**

**LOCATION OF
DUNE ALTERNATIVE
POINT BEACH SITE**

**STUDY SITES
MILFORD, CT
PLATE 13**



**FORT TRUMBULL AND
SILVER BEACHES SITE
MILFORD, CT
PLATE 14**



**STUDY SITES
MILFORD, CT
PLATE 15**

Environmental Considerations - Nells Island, an 840-acre salt marsh along the Housatonic River at the west end of the Cedar Beach site area, is a state owned wildlife sanctuary. Mud flats to the south of Nells Island are known as the best shorebird areas in the state (USFWS, 1987). Milford Point (shown on Plate 15), at the mouth of the Housatonic River, is a barrier beach, and a Connecticut Audubon Society Sanctuary. Over 230 bird species are known to occur in these areas, including the piping plover, a Federally listed threatened species which nests at Milford Point, and the Roseate tern, a Federally proposed endangered species which uses the areas during fall stopovers (USFWS, 1987). Another marsh area extends in back of the Silver Beach area, along Great Creek. This marsh has undergone recent restoration with a relocation of a portion of the creek, and installation of a flood control gate. The remainder of the Milford sites consist of residential homes along the beach front.

Effects associated with a dune and beach nourishment plan would include traffic and noise disturbance during transport of the sand from an inland site through the residential areas of Milford to the beach. Sand added to the beach areas could affect offshore shellfish areas through the transport and deposition of sand on the beds (USFW, 1987). Beach nourishment also has the potential to impact the piping plover through the destruction of potential nesting habitat. Other plant and shorebird species and associated habitat noted by the State of Connecticut as species of special concern and critical habitat would also be impacted. An alternative of obtaining sand from an offshore site would result in the disturbance and destruction of benthic marine resources. The alternative of raising structures would have no significant environmental impact on the resources of the study sites.

Economic Analysis - Plans evaluated at each site and their associated costs and benefits are shown in the table below.

	Number of Structures	First Cost	Annual Cost	Annual Benefits	Benefit Cost Ratio	Net Benefits
Burwells Beach						
1) Dune & Beach Nourishment		\$15,300,000	\$1,341,000	\$ 21,100	0.02	Negative
2) Raising Structures	110	\$ 3,080,000	\$ 270,000	\$ 21,100	0.08	Negative
Point Beach						
1) Dune & Beach Nourishment		\$18,700,000	\$1,639,000	\$572,300	0.35	Negative
2) Raising Structures	147	\$ 4,320,000	\$ 378,600	\$572,300	1.51	\$193,700
Bayview Beach						
1) Dune & Beach Nourishment		\$24,300,000	\$2,130,000	\$375,400	0.18	Negative
2) Raising Structures	136	\$ 4,000,000	\$ 350,600	\$375,400	1.07	\$ 24,800
Fort Trumbull/Silver Beaches						
1) Dune & Beach Nourishment		\$15,500,000	\$1,359,000	\$455,600	0.34	Negative
2) Raising Structures	401	\$11,230,000	\$ 984,000	\$455,600	0.46	Negative
Seaview Avenue/Broadway						
1) Dune & Beach Nourishment		\$32,300,000	\$2,830,000	\$274,800	0.10	Negative
2) Raising Structures	252	\$ 7,060,000	\$ 619,000	\$274,800	0.44	Negative
Cedar Beach						
Raising Structures	115	\$ 3,220,000	\$ 282,000	\$185,700	0.66	Negative

Although dune and beach nourishment projects are not economically justified at any of the five sites investigated, raising structures is justified at Point Beach and Bayview Beach. Costs of raising structures at these two locations was evaluated further by estimating the average size of first floor area for homes in the 100 year flood plain. This size was developed based on contour mapping provided by the City of Milford. This size was multiplied by the estimated cost of \$28.00 per square foot to raise a wood-frame structure. The average first floor area of homes at these sites is about 1,050 square feet, resulting in an average raising cost of \$29,400.

Based on the above analysis, further investigation of the feasibility of raising homes at the Point Beach and Bayview Beach sites is recommended. In addition, early warning and evacuation of residents is suggested for all flood prone areas along Milford's coast.

STRATFORD

Sites and Alternatives studied - Five sites in Stratford were initially identified for study. These sites were: Broad Street/Ferry Creek, Main Street/Airport, Lordship/Beach Drive, Surf Avenue/ Rt. 113, and Long Beach.

The Broad Street/Ferry Creek site consists of several homes and commercial establishments that are susceptible to tidal flooding from Ferry Creek (see Plate 16). During initial investigations of the feasibility of a dike or floodwalls in this area it was determined that either plan would require a street gate at Ferry Boulevard. Dikes or walls would also cause access problems to businesses and other activities in the area. Due to these problems, development of a structural plan at this site concentrated on road raising. Raising Broad Street to act as a dike would consist of several elements. To provide 100-year flood protection the road surface would be raised to elevation 13.1 feet NGVD. This would include raising the Ferry Boulevard - Broad Street intersection and new headwalls, culverts and gates at Ferry Creek. Raising of structures was not feasible because most commercial buildings are of slab-on-grade construction. Floodproofing was not practical due to the type of structure and disruption caused by individual ring walls.

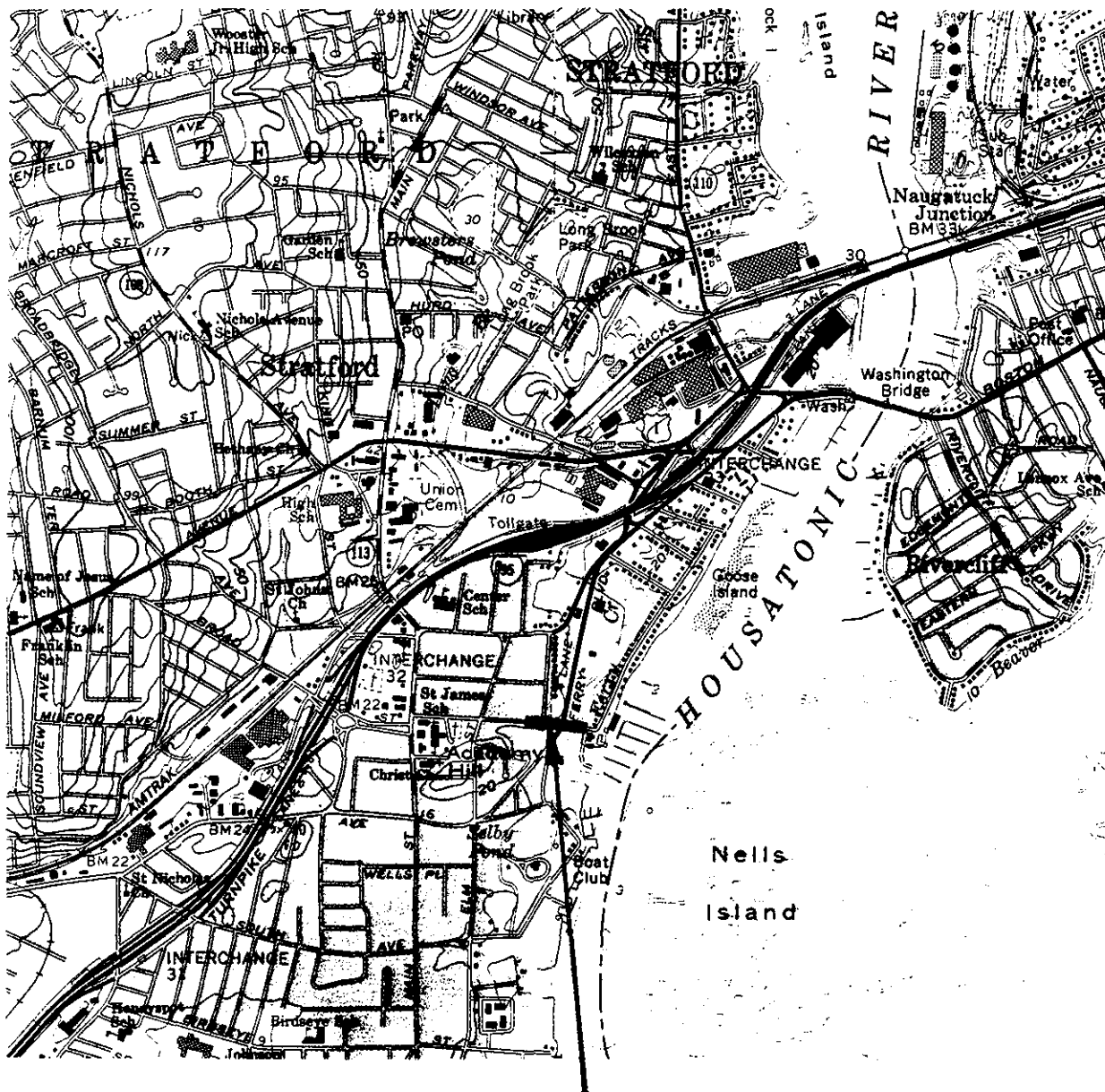
The Main Street/Airport site was determined to have no significant Federal interest. The problem in the area consists of street flooding of a small section of Main Street (Rt. 113) near the airport. It is recommended that State and local interests undertake the raising of the low section of the road because Main Street is one of only two evacuation routes out of the Lordship area in the event of a flood emergency.

The Lordship/Beach Drive site consists of summer homes and year round residences ranging from small cottages to large two-story buildings. As shown on Plate 17, the majority of the site is directly on the beach, and the density is high with very little space between adjacent structures. Raising homes appears to be the only feasible alternative, along with flood warning and excavation.

The Surf Avenue/Route 113 site was determined to have no significant Federal interest. Any flooding in the area would be of little consequence as there are few structures in the area and the streets are not critical for evacuation purposes. It is recommended that State and local interests examine the possibility of road raising at this site.

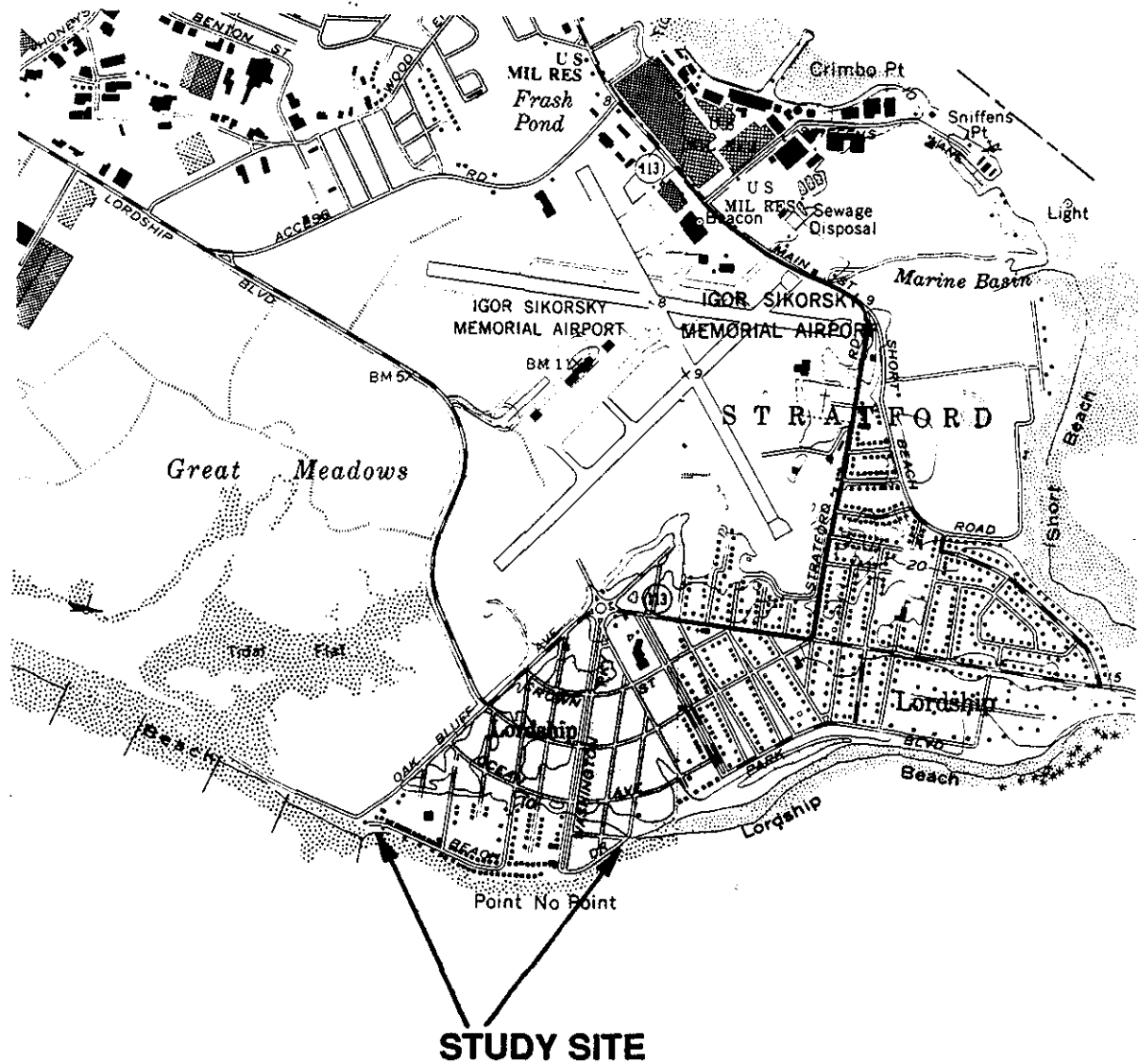
The Long Beach site (see Plate 18) consists of summer cottages built on a barrier beach. The land that the cottages are built on is leased by the Town to the cottage owners on a short-term basis. The best solution to the problem of potential flood damages is for the Town not to renew the leases, and require the owners to remove the buildings when the current leases expire. Although there is an institutional solution to the flood problem, raising structures and warning and evacuation were studied further.

Environmental Considerations - Ferry Creek is a small tidal creek that flows into the Housatonic River. The creek is bordered by Phragmites and scattered patches of *Spartina alterniflora*, with disturbance noted by pilings located in the creek bed, and associated development along Broad Street. A dike would encroach on the wetland vegetation along the creek shoreline.

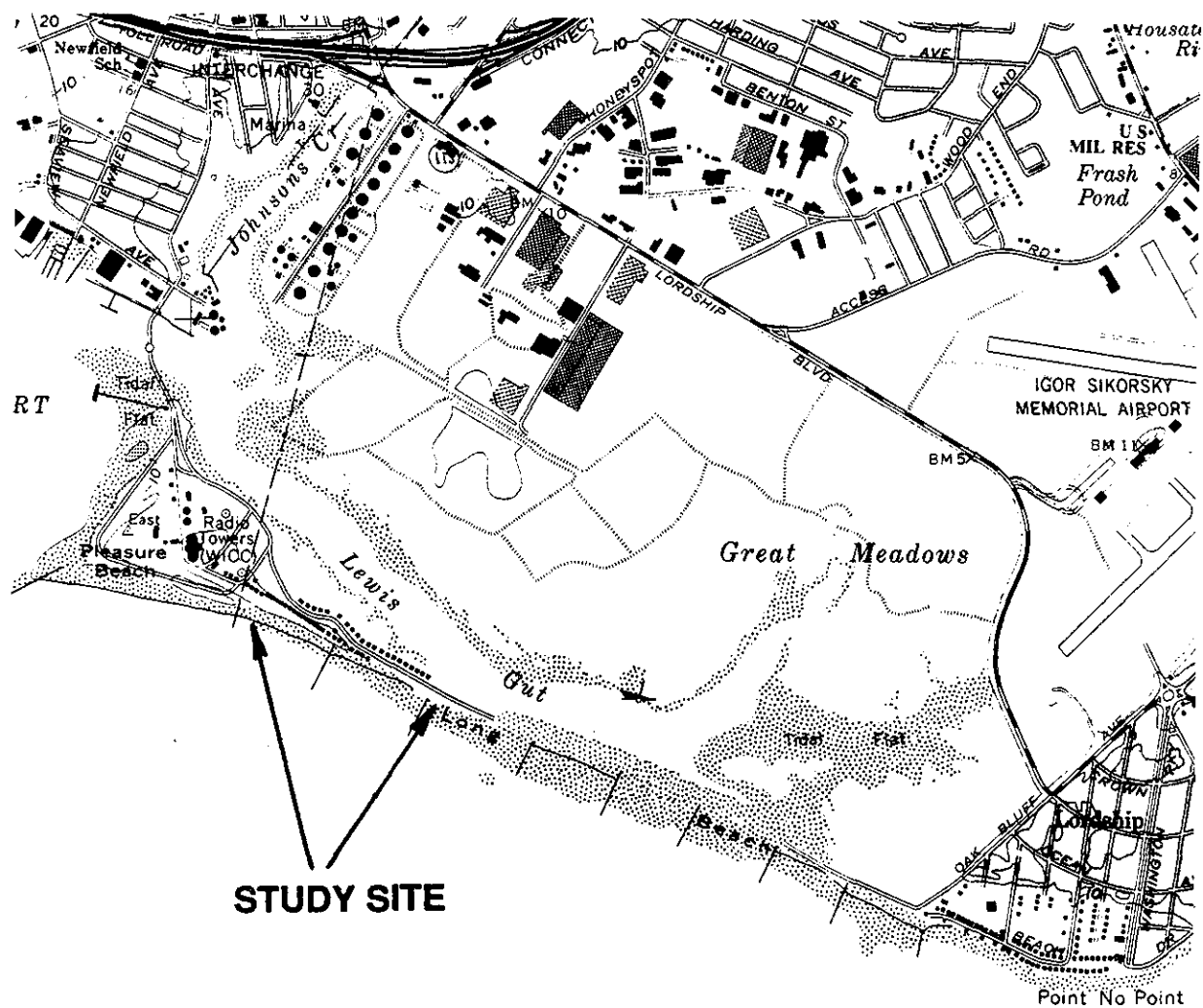


**LOCATION OF ROAD
RAISING ALTERNATIVE**

**BROAD STREET AND
FERRY CREEK SITE
STRATFORD, CT
PLATE 16**



**LORDSHIP AND
BEACH DRIVE SITE
STRATFORD, CT
PLATE 17**



**LONG BEACH SITE
STRATFORD, CT
PLATE 18**

The Lordship Beach area is a residential and summer home community between the beach area on Long Island Sound and the Bridgeport Municipal Airport. Lordship Beach is a pebbly/sandy beach, with structures sitting directly on the beach, with pilings in the water at high tide. There are no environmental concerns associated with nonstructural plans at this Stratford site.

Economic Analysis - The following table presents a comparison of costs and benefits of alternatives evaluated in Stratford.

	Number of Structures	First Cost	Annual Cost	Annual Benefits	Benefit Cost Ratio	Net Benefits
Broad Street/Ferry Creek- Road Raising		\$ 460,000	\$ 41,300	\$ 33,200	0.82	Negative
Lordship/Beach Drive Raising Structures	123	\$ 3,440,000	\$ 301,500	\$ 140,600	0.47	Negative
Long Beach Raising Structures	43	\$ 1,200,000	\$ 105,200	\$ 7,800	0.07	Negative

As shown above, plans developed for the Stratford sites are not justified economically. However, it is recommended that a flood warning and evacuation plan be developed and the possibility of raising evacuation routes be given further consideration by non-Federal interests. Consideration should also be given to reducing damages at the Long Beach site by not renewing leases of town owned flood prone property.

BRIDGEPORT

Sites and Alternatives Studied - Two sites were originally identified for study; Pleasure Beach and Seaside Park/Cedar Creek. Both of these sites were determined to have no potential Federal interest due to the apparent lack of significant potential damage. Most of the flood prone area is undeveloped park land with very few buildings subject to damage. No other evidence of flood damage potential was available to identify a problem at any other area, nor did City or State Officials indicate a need to study Bridgeport. Consequently, of the various initial alternatives considered, which included raising roads, floodproofing structures, dikes, and flood warning and evacuation, only the latter may be applicable for future non-federal implementation. As a result, no further study of flooding in Bridgeport was conducted.

FAIRFIELD

Sites and Alternatives Studied - Four contiguous sites in Fairfield were initially identified for study. These sites included: Ash Creek, Jennings Beach, Fairfield Beach/Road, and Pine Creek. Although identified as four sites (two (2) on Table 7), this area is one large floodplain extending from a point about 1,000 feet west of the Pine Creek outlet (near Kensie Point) to Ash Creek. These sites are primarily residential areas comprising summer cottages, permanent homes and new condominium developments, with a large number of homes located on the barrier beach. All new development or major modifications are required to have first floor elevations above the 100-year flood frequency level. These floodplain requirements are administered by the Town and required by FEMA as part of the flood insurance program. A sizeable portion of the Town of Fairfield is contained within the study area.

Alternatives originally considered for these sites included dune restoration/construction and beach nourishment, dikes, raising structures, relocation, road raising, bulkhead reconstruction, and flood warning and evacuation. Only raising structures and flood warning and evacuation remain as potential alternatives for all sites. An extensive plan of sand dune construction and beach nourishment, and diking to protect a large portion of Fairfield was considered, as was the possibility of raising the height of existing locally constructed dikes. Dune restoration and beach nourishment along the coast would not be effective in preventing flooding to backshore areas as floodwaters would circumvent this coastal work. Dikes are also required along Pine Creek and Ash Creek to provide complete protection to this area. Raising existing bulkheads along Fairfield Beach Road was not feasible because of the excessive cost required to provide adequate and effective protection. Relocation is not feasible due to the institutional and physical problems associated with relocating such a large number of homes and people.

The large comprehensive plan to protect the majority of the flood zone would consist of several elements. Starting at the southwest end of the floodplain, the project would include 1) a dike about 4600 feet in length along Old Dam Road, 2) a tide gate and navigation structure across Pine Creek, 3) approximately 9900 feet of dune restoration/construction and beach nourishment along the shoreline, 4) about 3700 feet of dike in the Jennings Beach - Ash Creek area and 5) a dike about 2100 feet long adjacent to Turney Creek. The dune would have a top elevation of 17 feet NGVD and the majority of dikes, which would not be subject to direct wave action, would be at elevation 14.0 feet NGVD. The approximate location of this plan is shown on Plate 19.

The possibility of raising, strengthening and extending the existing local dikes was also considered during the screening process. However, due to the extensive nature of the existing protective system, a complete engineering survey would be required to determine the exact limits and composition of existing dikes and other flood control works. Inasmuch as a detailed evaluation of this type was beyond the scope of this reconnaissance study, a cost estimate for this plan could not be developed. Although existing structures could be raised or strengthened with a minimum of additional impact on the surrounding area, the impacts associated with lengthening this system would require careful evaluation. Further study of this alternative and its impacts should be carried out in any subsequent feasibility stage investigation.

Environmental Considerations - The extensive Pine Creek tidal marsh area at the southern end of the project site extends in back of the homes along Fairfield Beach. There are expansive stands of *Spartina alterniflora* and *Spartina patens* that continue upstream to the center of Fairfield. This marsh is presently under restoration by the local Conservation Commission--old tide gates have been removed and the dike near Wakeman Island has been breached to restore tidal flushing in the marsh. The *Phragmites* is dying off, and *Spartina alterniflora* is growing well. Structural solutions in the Pine Creek marsh area could significantly impact these restoration efforts and be in conflict with coastal zone policies.

Ash Creek, which flows into Long Island Sound next to Jennings Beach at the northern end of the project site, is another typical tidal creek. The eastern side of the creek is characterized by sandy shoals exposed at low tide, with *Spartina alterniflora* and *Spartina patens* marshes extending back to the upland areas. A local marina facility is located on the western side of the creek. On the backshore of Jennings Beach, the local community built a large rock-filled dune about 8 years ago, and planted the dune with *Ammophila breviligulata*, American beach grass. Jennings Beach is a highly used town beach. Construction of a dike or other flood control works along Ash Creek would have a significant impact on environmental resources in this area.

To summarize, the comprehensive flood protection plan in Fairfield could significantly impact the coastal resources in the Pine and Ash Creek areas. This plan would be in conflict with the coastal zone policies of the State of Connecticut, and would also require extensive review under Section 404 of the Clean Water Act.

There are no significant environmental concerns associated with the nonstructural alternative of raising homes in these areas.

Economic Analysis- The economic analysis of the Fairfield flood zone was more complex than most. To take into consideration the effect of existing locally constructed dikes and other protective works, the Fairfield flood zone from the Pine Creek area to Ash Creek was divided into three zones. A cursory hydrologic review of the flood protection provided by locally constructed flood control works was conducted for each zone. Zone 1 encompasses the majority of the flood prone area from Kensie Point to Ash Creek. This area is protected from frequent flood events by dikes adjacent to Pine Creek and Ash Creek, and recent dune reconstruction along Jennings Beach. Included in this area are over 1550 structures. Zone 2 includes about 120 homes along the southwest end of Fairfield Beach to Pine Creek Point and receives no protection from ocean tidal flood levels. Zone 3 is a small zone of about 60 homes located along the center of Fairfield Beach Road. These homes are currently protected from frequent flooding by a bulkhead along Pine Creek.

Cost and benefits of each evaluated plan are shown in the following table.

	Number of Structures	First Cost	Annual Cost	Annual Benefits	Benefit Cost Ratio	Net Benefits
Dune and Dike Alternative (Protects Zones 1 and 2)		\$47,000,000	\$4,120,000	\$3,160,700	0.77	Negative
Raising Structures						
Zone 1	1152	\$33,870,000	\$2,968,700	\$3,105,500	1.05	\$136,800
Zone 2	83	\$2,440,000	\$213,900	\$92,100	0.43	Negative
Zone 3	45	\$1,320,000	\$115,700	\$55,200	0.48	Negative

Of the plans evaluated in Fairfield, only raising structures in zone 1 is economically justified. The costs of this plan were developed by establishing an average size of the first floors of homes in the area. Based on information obtained from photogrammetric maps provided by the Town of Fairfield, this average size was determined to be about 1050 square feet.

Inasmuch as raising homes in zone 1 is economically justified, it is recommended that further study in this area include an analysis of the feasibility of raising the existing local protective works. considering the vulnerable position of home owners along the southwest end of Fairfield Beach Road, it is also recommended that warning and evacuation be given serious consideration by non-Federal interests.

WESTPORT

Sites and Alternatives Studied - Four sites in Westport were initially identified for study. These sites included: Compo Mill Beach, Old Mill Beach, Compo Beach, and Saugatuck Shores.

The Compo Mill Beach site consists of a few homes along the beach with several more set back behind these. Alternatives originally developed for the site included relocation, raising homes, and flood warning and evacuation. Relocation, was determined to be not feasible due to the large size and high market value associated with many of the homes, in addition to the problems of moving people from what they consider to be a very desirable location. Raising homes and flood warning and evacuation appear feasible, however.

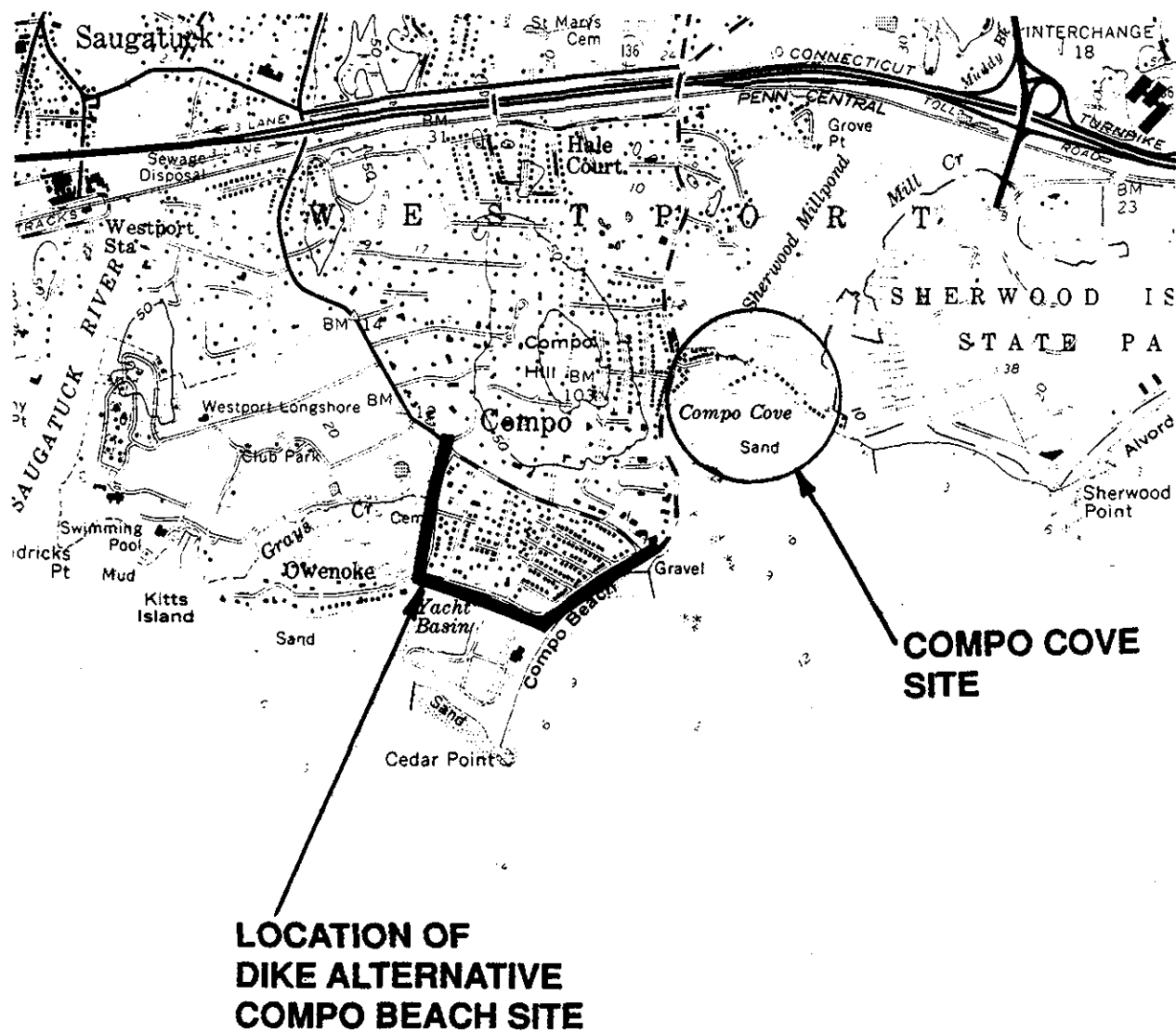
The Old Mill Beach site is comprised of mostly year round homes. the only feasible alternatives for this site are raising structures and flood warning and evacuation. This site and the Compo Mill Beach site were combined into one study zone and renamed the Compo Cove site, shown on Plate 20.

The Compo Beach site is composed of a densely developed residential neighborhood set in an area of low elevation. It is surrounded by higher ground on all sides, and after the coastal high ground is overtopped, the interior areas flood. Alternatives retrained for further study in this area included diking, raising structures and flood warning and evacuation. Plate 20 indicates the location of this site and the approximate limits of the dike alternative.

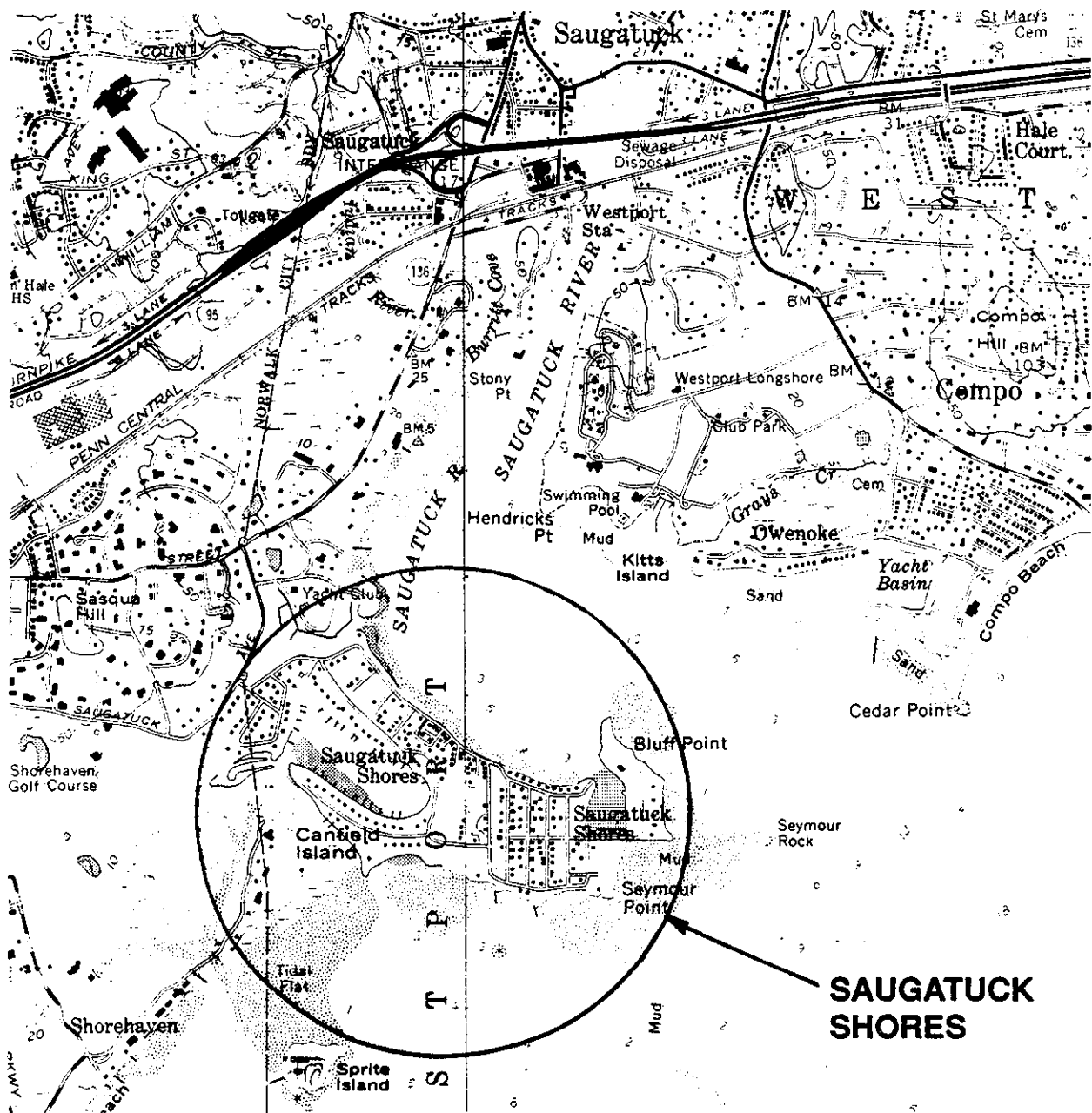
The Saugatuck Shores site consists of large, expensive homes built in an area of very low elevation that is surrounded by Long Island Sound on three sides (See Plate 21). Initially, road raising, home raising, and flood warning and evacuation were considered as alternative protective measures. Road raising was determined to be ineffective in preventing floods, but would prove useful for evacuation purposes. Presently, Harbor Road is the primary escape route in the event of a flood. Raising Harbor Road and possibly others such as Canal Road would facilitate evacuation of the area, particularly the eastern portion of the study area. Raising structures, although difficult due to the large size and unique appearance of some homes, was studied further.

Environmental Considerations - Identified sites are areas of large homes located along the shoreline of the Saugatuck River and Long Island Sound. Salt marsh areas border the tidal creeks that flow through the community. A dike under study for the Compo Beach area would encircle a low-lying area of homes north of the yacht basin bordered by Compo Beach Road on the south and west, Soundview Drive on the east and Compo Road on the north.

A flood control dike would encroach on the eastern edge of the Grays Creek salt marsh that forms the west boundary of the project. Impacts also include possible alteration of runoff patterns (USFWS, 1987). There are no environmental concerns associated with non-structural plans at sites in Westport.



**STUDY SITES
WESTPORT, CT
PLATE 20**



STUDY SITE
WESTPORT, CT
PLATE 21

Economic Analysis - The following tabulation presents the first cost, annual costs and benefits and benefit to cost ratio of evaluated plans in Westport.

	Number of Structures	First Cost	Annual Cost	Annual Benefits	Benefit Cost Ratio	Net Benefits
Compo Cove Raising Structures	60	\$ 2,300,000	\$201,600	\$ 474,900	2.36	\$ 273,300
Compo Beach Dike Plan		\$ 3,200,000	\$280,400	\$ 201,400	0.72	Negative
Raising Structures	229	\$ 6,410,000	\$561,800	\$ 201,400	0.36	Negative
Saugatuck Shores Raising Structures	150	\$7,660,000	\$671,400	\$1,824,800	2.72	\$1,153,400

This economic analysis determined that raising structures at Compo Cove and Saugatuck Shores is economically justified and warrants further study. First costs of raising structures at these two sites were based average first floor sizes of 1350 square feet for Compo Cove and 1800 square feet for Saugatuck Shores. These sizes were obtained from topographic maps obtained from the Town of Westport. Early warning and evacuation is recommended for all areas.

DISCUSSION OF FEASIBLE ALTERNATIVES

As a result of investigations presented in the preceding sections, economically feasible alternatives were developed for five sites in three of the eight study area communities. All justified plans involve raising of existing structures to protect them from the 100-year flood event.

Communities and sites where raising structures is economically justified, are shown below:

City of Milford

- 1) Point Beach
- 2) Bayview Beach

Town of Fairfield

- Zone 1 - Comprised of the majority of the floodplain between Kensie Point and Ash Creek

Town of Westport

- 1) Compo Cove
- 2) Saugatuck Shores

Cost of raising structures at these locations was based on existing mapping provided by the study area communities.

Raising homes in these areas would involve the following actions:

- 1) Raising the structure
- 2) Replacing or rebuilding the existing foundation; piles or foundation walls would be used.
- 3) Placing the structure on the elevated foundation
- 4) Extending utilities and rebuilding/extending access.
- 5) Relocating any utilities (heating system) that may have been located in a basement and subject to flooding.
- 6) Temporary relocation of building occupants during the construction period.

During the next stage of study, specific actions required at each property will be identified.

Although not identified as an economically justified alternative, further study of the feasibility of raising, strengthening and/or extending the existing local flood protection works in Fairfield is recommended. Detailed investigation of this extensive locally constructed system was beyond the scope of this reconnaissance study. However, due to the extensive floodplain and potential for flood damage, further study of this alternative appears warranted.

COORDINATION WITH OTHER FEDERAL AGENCIES

The U.S. Fish and Wildlife Service (FWS), Ecological Services, Concord Field Office, participated in a field visit with Corps staff to the study area in September 1987. A Planning Aid letter dated October 9, 1987 was provided (see Appendix E). The Planning Aid letter addressed only those alternatives having the potential for impacting significant resources. Alternatives such as floodproofing structures and providing flood warnings are preferred by FWS because of their lack of impact.

FWS stated concerns for three sites in the study area should structural alternatives be considered: Compo Beach in Westport, Old Field Creek in West Haven, and the Milford site. They recommended nonstructural alternatives for these sites.

The National Marine Fisheries Service, Milford field office, participated in a field visit with Corps staff to the Fairfield site in September 1987 (Appendix E). The other alternative sites were discussed during this field meeting.

A letter provided to the New England Division, dated October 13, 1987, stated that the project, as presently proposed, will have no direct, adverse impacts to the resources for which the agency is responsible.

The U.S. Environmental Protection Agency, Region 1 office, provided a letter dated October 22, 1987 (Appendix E) to NED commenting on the proposed project. The office was unable to participate in the field site visits. EPA prefers the non-structural alternatives based on their minimal environmental impact. They recommended against structural flood damage control in Westport and West Haven, and beach nourishment in Milford because of impacts to coastal marshes and piping plover nesting habitat.

LOCAL COOPERATION

The State of Connecticut is the non-Federal sponsor for further study. Involvement by the State of Connecticut, DEP, in tidal flood problems in the study area has been continuous. In a letter dated November 7, 1983, this office provided the Corps with a list of priority areas for additional studies along their coastline. Five of the eight communities included in this study were included on that list.

There have been numerous coordination meetings, workshops and field investigations with various staff members of the Connecticut Department of Environmental Protection. They assisted in identifying flood prone areas, made recommendations as to sites to be studied and suggested alternative flood damage reduction measures to be considered. Upon initiation of the study, points of contact were established with the eight study area communities. Copies of letters appointing these representatives or providing study information are contained in Appendix E. Coordination meetings were held with representatives of these communities, often in conjunction with the State, to discuss sites and alternatives.

Although nonstructural flood protection measures are encouraged by State policy (see CT/DEP letter dated February 18, 1987, Appendix E), structural plans were evaluated as necessary. It became obvious early in the study, however, that very few structural alternatives were economically feasible, or institutionally or environmentally acceptable.

Of the structural plans evaluated, only one requires additional study. This is raising, strengthening or extending the existing local flood control works in Fairfield.

The non-Federal sponsor, the Connecticut, DEP, by letter dated June 7, 1988, (see Appendix E) outlined their support for further study and willingness to enter into negotiation of a Feasibility Cost Sharing Agreement (see Appendix A). This letter supported further study of the nonstructural alternative of raising structures at five study sites, and outlined their concerns regarding modifying the existing protective works in Fairfield.

SECTION IV

FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

FINDINGS AND CONCLUSIONS

As a result of evaluation and coordination with the Connecticut DEP of alternative flood damage reduction measures at identified study sites, it was agreed that raising of structures, where economically justified, warrants further study in the feasibility phase. In addition, further study of the possibility of modifying town constructed protective works in Fairfield is required. Flood forecast, warning and evacuation would also be studied in conjunction with other identified alternatives.

The preferred damage reduction alternative is raising structures so that the first floor is above the FEMA 100-year wave crest flood elevation as a minimum. Inasmuch as raising structures is economically justified at five sites and preventing damage is preferable to paying for flood damage and repairing damage after a flood, there is a definite Federal interest in pursuing feasibility scope investigations.

The estimated costs and benefit to cost ratios of raising structures at these five sites are presented below. The location of these areas are shown on Plate 22.

Location	Cost	Benefit to Cost Ratio
Westport		
Saugatuck Shores	\$7,660,000	2.72
Compo Cove	\$2,300,000	2.36
Milford		
Bayview Beach	\$4,000,000	1.07
Point Beach	\$4,320,000	1.51
Fairfield	\$33,870,000	1.05

Inasmuch as the estimated Federal portion of the first cost of project implementation at four of these sites is within the \$5 million limit of Section 205 of the 1948 Flood Control Act, as amended, it is concluded that further study of these areas could be conducted under this authority. Consequently, four separate Section 205 investigations should be initiated. These include Saugatuck Shores and Compo Cove in Westport, and Bayview and Point Beaches in Milford. Each project will be complete within itself and a separate Feasibility Cost Sharing Agreement (FCSA) will be prepared for each site under Section 205.

The next stage of this Congressionally authorized study will be negotiation of a FCSA with the State of Connecticut DEP. A model FCSA and current estimate of costs to complete this feasibility study are included in Appendix A.

It is also concluded that State of Connecticut communities in the study area should continue to update and maintain existing flood forecast, warning and evacuation plans. Information contained in this report, particularly Appendices B, C and D, should prove useful to communities in the study area.

RECOMMENDATIONS


Based on the results of this reconnaissance study, further study of flooding at five locations in the communities of Milford, Westport and Fairfield is warranted. The flood control alternatives identified are economically justified and eligible for further Federal assistance. The cost of raising structures at four of these sites are likely to fall within the 205 limitation and are therefore recommended for study under the Section 205 Continuing Authorities Program.

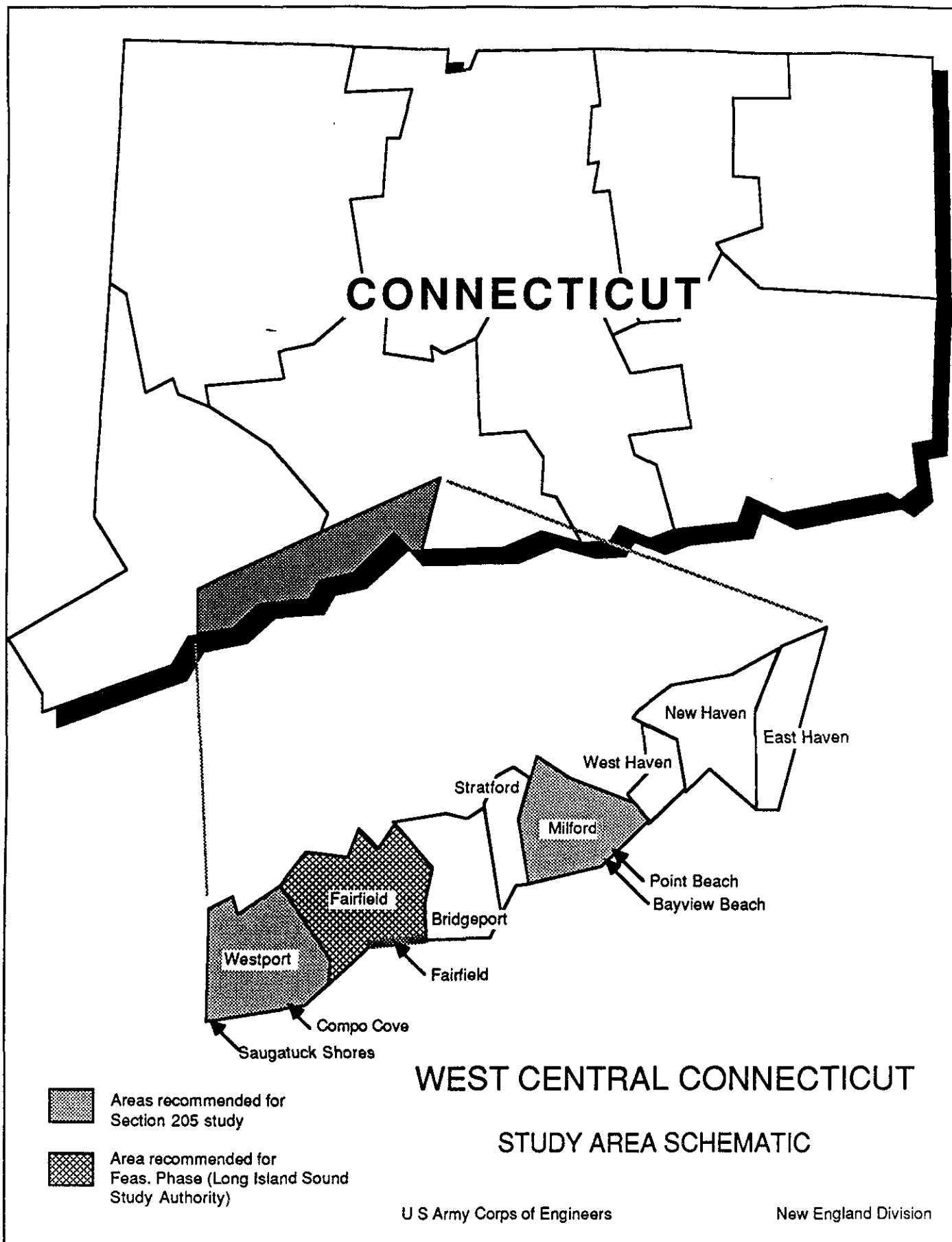
The sponsor of the study, the State of Connecticut, Department of Environmental Protection, has been involved in this reconnaissance study from its conception. State and community representatives have assisted in identifying potential problem areas and screening alternatives. Our findings are in agreement with the state's policies and statutes concerning coastal floodplains, and we look forward to continued strong state involvement as we move forward into more detailed study efforts.

I recommend that any further flood control studies and implementation of project to prevent flooding by raising structures at four sites be conducted under the Section 205 Small Flood Control Projects Continuing Authority Program. These specific sites are: Point Beach and Bayview Beach in Milford; and Compo Cove and Saugatuck Shores in Westport.

I further recommend that feasibility phase studies be conducted in Fairfield to determine the desirability of raising flood prone structures or improving the existing locally constructed protective system. Further studies will be cost shared with the State of Connecticut in accordance with the Water Resources Development Act of 1986, Public Law 99-662.

9 June 88
Date


THOMAS A. RHEN
Colonel, Corps of Engineers
Commander



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ACKNOWLEDGMENTS

This report was prepared by Douglas A. Cleveland, and Richard W. Heidebrecht, Project Manager; under the supervision of Arthur F. Doyle and Peter E. Jackson, Chief Comprehensive River Basin Section; Donald W. Martin, Chief, Basin Management Branch; and Joseph L. Ignazio, Chief, Planning Division. Others who contributed to this report include the following:

Marianne N. Matheny - Economic Analysis

David Keddell - Economic Analysis

Susan E. Brown - Environmental Analysis

Marie Lynn Bourassa - Archeological Study

Thomas C. Bruha - Dune Restoration and Beach Nourishment Analysis

Charles J. Wener - Hydrology Analysis

Patrick V. Tornifoglio - Engineering Design

Robert McDonald - Geotechnical

Edward Fallon - Real Estate

Anna V. Parfenuk - Word Processing

Cheryl Baer - Word Processing

Bill Kilroy - Technical Assistance

Phil Wang - Technical Assistance

Tom Marcotte - Technical Assistance

Mike Walsh - Technical Assistance

Chris Zevitas - Technical Assistance

Matt Keefe - Technical Assistance

Kimber Lynn Zinger - Technical Assistance

Representatives of the State of Connecticut, Department of Environmental Protection, with whom this study was coordinated include:

Mary Ann Dickinson

Dan Rothenberg

Ron Rozsa

Chuck Berger

Alan Williams

Tom Ouellette
Chris Recchia
Margaret Beauharnois
Lynn Stoddard
George Wisker
Dave Fox

Representatives of the eight study area communities with whom this study was coordinated include:

East Haven - Charles Boster, Town Planner
New Haven - Leonard Smith, City Engineer
West Haven, Abdul Quadir, City Engineer
Milford - John Casey, City Engineer
Stratford - Charles Buynovsky, Engineering Supervisor
Bridgeport - Michael Nidoh, Assistant Planning Director
Fairfield - Joseph Devonshuk, Director, Planning and Zoning Commission
Westport - Steve Edwards, Deputy

Individuals representing other Federal agencies were also consulted during this study, including the following:

Roger Hogan - U.S. Fish and Wildlife Service
Mike Ludwig - National Marine Fisheries Service
Tom Addison - Environmental Protection Agency

Appendix A

Draft Feasibility Cost Sharing Agreement and Feasibility Phase Cost Estimate

APPENDIX A

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APPENDIX A

MODEL AGREEMENT
BETWEEN THE UNITED STATES OF AMERICA
AND
THE STATE OF CONNECTICUT
FOR THE WEST CENTRAL CONNECTICUT
TIDAL-FLOOD MANAGEMENT FEASIBILITY STUDY

THIS AGREEMENT, entered into this _____ day, of _____, 19____, by and between the United States of America (hereinafter called the "Government"), represented by the Contracting Officer executing this Agreement, and (Sponsor Name) (hereinafter called the "Sponsor"),

WITNESSETH, that

WHEREAS, the Senate Public Works Committee, by a Resolution adopted 22 September 1970, has requested

"That the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act approved June 13, 1902, be and is hereby requested to review the report on the Land and Water Resources of the New England-New York Region, transmitted to the President of the United States by the Secretary of the Army on April 27, 1956, and subsequently published as Senate Document Numbered 14, Eighty-fifth Congress, with a view to determining the advisability of improvements in Long Island Sound, New York and Connecticut in the interest of flood control, navigation and related purposes with due consideration for enhancing the quality of the environment."

WHEREAS, the Corps and related Engineers has conducted a reconnaissance study of tidal flooding problems in the West Central Connecticut portion of Long Island Sound pursuant to this authority, and has determined that further study in the nature of a "Feasibility Phase Study" (hereinafter called the "Study") is required to fulfill the intent of the study authority and to complete the determination of the extent of the Federal interest in determining the advisability of improvements in Fairfield, Connecticut in the interest of tidal flood control and related purposes; and

WHEREAS, the Sponsor and the Government both understand that entering into this agreement in no way obligates either party to implement a project and that whether a project is supported for authorization and budgeted for implementation depends upon the outcome of this feasibility study and whether the proposed solution is consistent with the Principles and Guidelines and with the budget priorities of the Administration and that at the present time, favorable budget priority is being assigned to projects providing primarily commercial navigation and flood or storm damage reduction outputs ; and

WHEREAS, the Water Resources Development Act of 1986 (P. L. 99-662) specifies the cost sharing requirements applicable to the study;

NOW THEREFORE, the parties agree as follows:

ARTICLE I - DEFINITIONS

For the purposes of this Agreement:

a. The term "Study Cost" shall mean all disbursements by the Government pursuant to this Agreement, whether from Federal appropriations or from funds made available to the Government by the Sponsor, and all Negotiated Costs of work performed by the Sponsor pursuant to this Agreement. Such costs shall include, but not be limited to: labor charges; direct costs; overhead expenses; supervision and administration costs; and contracts with third parties, including termination or suspension charges; and any termination or suspension costs (ordinarily defined as those costs necessary to terminate ongoing contracts or obligations and to properly safeguard the work already accomplished associated with this Agreement.

b. The term "Study Period" shall mean the time period for conducting the Study, commencing with the issuance of initial federal feasibility funds following the execution of this Agreement, and ending when the report is submitted to the Office of Management and Budget (OMB) by the Assistant Secretary of the Army for Civil Works (ASA(CW)) for review of consistency with the policies and programs of the President.

c. The term :Negotiated Cost: is the fixed fee for a work item to be accomplished by the sponsor as in-kind services a specified in the Scope of Studies incorporated herein and which is acceptable to both parties.

ARTICLE II - OBLIGATIONS OF PARTIES

a. The Sponsor and the Government, using funds contributed by the Sponsor and appropriated by the Congress, shall expeditiously prosecute and complete the Study, currently estimated to be completed in ____ months from the date of this Agreement, substantially in compliance with Article III herein and in conformity with applicable Federal laws and regulations, the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies, and mutually acceptable standards of engineering practice.

b. The Government and the Sponsor shall each contribute, in cash and in-kind services, fifty (50) percent of all Study Costs, which total cost is currently estimated to be \$_____, as specified in Article IV herein; provided, that the Sponsor may,

consistent with applicable Federal statutes and regulations, contribute up to 25 percent of the Study Costs as in-kind services; provided further, the Government shall not obligate any cash contribution by the Sponsor toward Study Costs until such cash contribution has actually been made available to it by the Sponsor.

c. The award of any contract with a third party for services in furtherance of this Agreement which obligates Federal appropriations shall be exclusively within the control of the Government. The award of any contract by the sponsor with a third party for services in furtherance of this agreement which obligates funds of the Sponsor and does not obligate Federal appropriations shall be exclusively within the control of the Sponsor, but shall be subject to applicable Federal statutes and regulations.

d. The Government and the Sponsor shall each endeavor to assign the necessary resources to provide for the prompt and proper execution of the Study and shall, within the limits of law and regulation, conduct the study with maximum flexibility as directed by the Executive Committee established by Article V, herein.

e. The Government will not continue with the Study if it determines that there is no solution in which there is a Federal interest or which is not in accord with current policies and budget priorities unless the Sponsor wishes to continue under the terms of this Agreement and the Department of Army Grants an exception. If a study is discontinued, it shall be concluded according to Article XII and all data and information shall be made available to both parties.

f. The Sponsor may wish to conclude the Study if it determines that there is no solution in which it has an interest or which is not in accord with its current policies and budget priorities. When such a case exists the study shall be concluded according to Article XII and all data and information shall be made available to both parties.

ARTICLE III - SCOPE OF STUDIES

Appendix A, the Scope of Studies, is hereby incorporated into this Agreement. The parties to this Agreement shall substantially comply with the Scope of Studies in prosecuting work on the Study. The following modifications, to be approved by the Executive Committee, shall require an amendment to this Agreement:

a. any modification which increases the total Study Costs by more than ____ percent (% to be negotiated with 15% maximum) (see Appendix A, page ____);

- b. any modification in the estimated cost of a Study work item or any obligation for a Study work item, which changes the total cost of that work item by more than ____ percent (% to be negotiated with 15% maximum) (see Appendix A, page ____);
- c. any extension of the completion schedule for a Study work item of more than thirty (30) days (see Appendix A, page ____); or
- d. any reassignment of work items between the Sponsor and the Government (see Appendix A, page ____).

ARTICLE IV - METHOD OF PAYMENT

- a. The Government shall endeavor to obtain during each fiscal year the appropriation for that fiscal year at least in the amounts specified in the Scope of Studies incorporated herein. Subject to the enactment of Federal appropriations and the allotment of funds to the Contracting Officer, the Government shall then fund the Study at least in the amounts specified in the Scope of Studies herein.
- b. The Sponsor shall endeavor to obtain during each Government fiscal year the cash contribution for that government fiscal year at least in the amounts specified in the Scope of Studies incorporated herein and, once it has obtained funds for a cash contribution, shall make such funds available to the Government. The Government shall withdraw and disburse funds made available by the Sponsor subject to the provisions of this Agreement.
- c. Funds made available by the Sponsor to the Government and not disbursed by the Government within a Government fiscal year shall be carried over and applied to the cash contribution for the succeeding Government fiscal year; provided, that upon study termination any excess cash contribution shall be reimbursed to the Sponsor after a final accounting, subject to the availability of appropriations, as specified in Article XII herein.
- d. Should either party fail to obtain funds sufficient to make obligations or cash contributions or to incur Study Costs in accordance with the schedule included in the Scope of Studies incorporated herein, it shall at once notify the Executive Committee established under Article V herein. The Executive Committee shall determine if the Agreement should be amended, suspended, or terminated under Article XII herein.

ARTICLE V - MANAGEMENT AND COORDINATION

- a. Overall study management shall be the responsibility of an Executive Committee consisting of (insert names and titles). (The Executive Committee shall normally include the District Engineer; District Chief, Planning Division; and the Sponsor's counterparts.)
- b. To provide for consistent and effective communication and prosecution of the items in the Scope of Studies, the Executive Committee shall appoint representatives to serve on a Study Management Team.
- c. The Study Management Team will coordinate on all matters relating to prosecution of the Study and compliance with this Agreement, including cost estimates, schedules, prosecution of work elements, financial transactions and recommendations to the Executive Committee for termination, suspension, or amendment of this Agreement.
- d. The Study Management Team will prepare periodic reports on the progress of all work items for the Executive Committee.

ARTICLE VI - DISPUTES

- a. The Study Management team will endeavor in good faith to negotiate the resolution of conflicts. Any dispute arising under this Agreement which is not disposed of by mutual consent shall be referred to the Executive Committee. The Executive Committee shall resolve such conflicts or determine a mutually agreeable process for reaching resolution of for termination under Article XII herein.
- b. Pending final decision of a dispute hereunder, or pending suspension or termination of this Agreement under Article XII herein, the parties hereto shall proceed diligently with the performance of this Agreement.

ARTICLE VII - MAINTENANCE OF RECORDS

The Government and the Sponsor each shall keep books, records, documents and other evidence pertaining to study costs and expenses incurred pursuant to this Agreement to the extent and in such detail as will properly reflect total Study costs. The Government and the Sponsor shall maintain such books, records, documents and other evidence for inspection and audit by authorized representatives of the parties to this Agreement. Such material shall remain available for review for a period of three (3) years following the termination of this Agreement.

ARTICLE VIII - RELATIONSHIP OF PARTIES

a. The parties to this Agreement act in an independent capacity in the performance of their respective functions under this Agreement, and neither party is to be considered the officer, agent, or employee of the other.

b. To the extent permitted by applicable law, any reports, documents, data, findings, conclusions, or recommendations pertaining to the Study shall not be released outside the Executive Committee or the Study Management Team; nor shall they be represented as presenting the views of either party unless both Parties shall indicate agreement thereto in writing.

ARTICLE IX - OFFICIALS NOT TO BENEFIT

No member of or delegate to the Congress, or other elected official, shall be admitted to any share or part of this Agreement, or to any benefit that may arise therefrom

ARTICLE X - FEDERAL AND STATE LAWS

In acting under its rights and obligations hereunder, the local sponsor agrees to comply with all applicable Federal and state laws and regulation, including section 601 of Title VI of the Civil Rights Act of 1964 (Public Law 88-352) and Department of Defense Directive 5500.II issued pursuant thereto and published in Part 300 of Title 32, Code of Federal Regulations, as well as Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army."

ARTICLE XI - COVENANT AGAINST CONTINGENT FEES

The local sponsor warrants that no person or selling agency has been employed or retained to solicit or secure this Agreement upon agreement or understanding for a commission, percentage, brokerage, or contingent fee, exception bona fide employees or bona fide established commercial or selling agencies maintained by the local sponsor for the purpose of securing business. For breach or violation of this warranty, the Government shall have the right to annul this Agreement without liability, or, in its discretion, to add to the Agreement of consideration, or otherwise recover, the full amount of such commission, percentage, brokerage, or contingent fee.

ARTICLE XII - TERMINATION OR SUSPENSION

a. This Agreement shall terminate at the completion of the Study Period; provided, that prior to such time and upon thirty (30) days written notice, either party may terminate or suspend this Agreement without penalty.

b. Within ninety (90) days upon termination of this Agreement the Study Management Team shall prepare a final accounting of Study costs, which shall display disbursements by the Government of Federal funds, cash contributions by the Sponsor, and credits for the Negotiated Costs of the Sponsor. Subject to the availability of funds, within thirty (30) days thereafter the Government shall reimburse the Sponsor for the excess, if any, of cash contributions and credits given over fifty (50) percent of total Study Costs. Within thirty (30) days thereafter, the Sponsor shall provide the Government any cash contributions required so that the total Sponsor share equals fifty (50) percent of total Study Costs.

IN WITNESS WHEREOF, the parties hereto have executed this Agreement as of the day and year first above written.

THE UNITED STATES OF AMERICA

STUDY SPONSOR

BY _____
Colonel, Corps of Engineers
Division Engineer
Contracting Officer

BY _____
(Title)

APPENDIX A - Scope of Studies

FEASIBILITY PHASE COST ESTIMATE

The following is a listing of the anticipated tasks to be accomplished during the feasibility phase and a preliminary estimate of their cost.

<u>Task</u>	<u>Cost</u>
Public Involvement	\$35,000
Institutional Studies	15,000
Demographic Studies	6,000
Cultural Resource Studies	8,000
Environmental Studies	22,000
Fish and Wildlife Studies	10,000
Economic Studies	16,000
Surveying and Mapping	22,000
Hydrology and Hydraulics	35,000
Foundations and Materials	50,000
Design and Cost Estimates	66,000
Real Estate Studies	60,000
Study Management	45,000
Plan Formulation	15,000
Report Preparation	<u>45,000</u>
TOTAL	\$450,000

Appendix B

Tidal Hydrology

WEST CENTRAL CONNECTICUT
TIDAL FLOOD MANAGEMENT STUDY

Tidal Hydrology
Appendix

Hydraulics and Water Quality Section
Water Control Branch
Engineering Division

New England Division
Corps of Engineers
02254-9149

September 1987

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FOREWORD

The main intent of this appendix is to provide a discussion of tidal hydrologic phenomena related to Corps planning of coastal related activities in the west-central Connecticut area. Additionally, it is hoped that this document will serve to provide a base of information useful to State, local, and private interests dealing with coastal improvements or regulatory functions in the study area. Questions regarding this report can be addressed to Mr. Charles Wener, Chief, Hydraulics and Water Quality Section at 617-647-8686.

1. ASTRONOMICAL TIDES

a. The Reason For Tides

The waters of the earth are free to respond to the gravitational attraction of the sun and moon somewhat independently from the response of the solid earth. Each particle of the earth is attracted toward the centers of the earth, moon and sun by a force which is proportional to the mass of the body and inversely proportional to the square of the distance to the center of the body.

The solid earth responds as though all of the force were applied at the center of the earth. Fluid particles, which are free to move, respond as though the force were applied at the center of each particle. The attractive force of the earth is directed along the vertical and is much stronger than the attractive force of the moon or sun near the surface of the earth. Thus the vertical component of the gravity fields of the sun and moon does not have any effect on the fluid motions of the earth. When the sun and moon are not immediately overhead, the attractive forces due to these bodies have components parallel to the surface of the earth that are not opposed by the gravitational attraction of the earth. These components of the gravitational fields of the sun and moon produce an acceleration of the fluid particles toward the subsolar and sublunar points and similar points on the opposite side of the earth.

The tide-generating force applied to any particle of the earth is the difference between the gravitational attraction of the sun or moon for that particle and the attraction of the sun or moon for the center of the earth. Since a difference is involved, the tide-generation force is inversely proportional to the cube of the distance between the bodies. As a result, the moon which is much smaller than the sun but much nearer the earth has a larger tide-generating force than the sun even though its gravitational force on the earth is less than one percent of that due to the sun.

At times of new moon and full moon the lunar and solar attractive forces are acting in the same direction. This position is called syzygy (pronounced siz-a-gee), and during this condition high water rises higher and low water falls lower so that the range of the tide is greater than average. Such tides are called spring tides, and the range is the spring range. When the moon is in its first and last quarters, the tidal forces of sun and moon oppose each other and the tide does not rise as high nor fall as low as the average. Such tides are called neap tides, and their range is called the neap range. (See Figure 1) A cycle of one spring tide and one neap tide is about 14-3/4 days in length. There is a time lag between the moon's phase and the tidal response, which varies in different localities; at Bridgeport Harbor near the center of the study area the tidal extremes lag about 38 hours behind the lunar phases.

The varying distance of the moon from the earth likewise affects the range of the tide. In its movement around the earth the moon describes an ellipse in a period of approximately 27-1/2 days. When the moon is in perigee, or nearest the earth, its tide-producing power is increased, resulting in an increased rise and fall of the tide. These tides are known as perigean tides, and the range is the perigean range. There is a time lag between lunar perigee and maximum tidal effect of about 58 hours at Bridgeport Harbor. If the occurrence of spring tide is coincident with the maximum tidal response to lunar perigee, the combined perigean spring tide results in an even greater tidal range.

When the moon's orbit is on or close to the equator (that is, when the declination is small), consecutive ranges do not differ much; morning and afternoon tides are very much alike (equatorial tides). As the declination increases, the difference between consecutive ranges increases and morning and afternoon tides begin to show decided differences. At the times of the moon's maximum semi-monthly declination (tropic tides), these differences are very nearly at a maximum. A complete cycle of equatorial and tropic tides takes approximately 27-1/3 days.

It is seen that the amplitude of the tide is modulated by several phenomena which have periods of the order of 28 to 30 days. The maximum tide ranges occur when two or more of these phenomena are nearly in phase. A complete sequence of tide ranges is approximately repeated at intervals of 19 years, which are referred to as metonic cycles. Consequently, a period of 19 years of observation is preferred for the establishment of tidal datum planes such as mean low water (MLW) and mean sea level (MSL). Wood (1978) has summarized a large volume of data which shows that the variability in tide range has a great effect on tidal flooding. He recommends that more attention be paid to the extreme ranges of astronomical tides.

b. Sample Hydrograph of Astronomical Tides

A hydrograph of the predicted astronomical tide in Bridgeport Harbor for January 1963 is shown in Figure 2. The variations in water level shown in this figure are reasonably typical of most Atlantic coast locations in the United States. A few high and low water elevations, referred to local mean sea level have been entered above or below the curve to provide perspective for the day to day changes in tide range in response to the phenomena discussed above. The hydrograph indicates that the predicted high tide elevation varied from 1.7 to 3.9 feet above the local mean sea level and the predicted low tide varied from 2.8 to 4.6 feet below the local mean sea level. It can also be seen that the maximum range for the month, 8.4 feet, was nearly double the minimum range, 4.5 feet. The variation in the astronomical tide range over a period of several years can be even greater. The predicted high water at Bridgeport may be as little as 1.2 or as much as 5.7 feet above the local mean sea

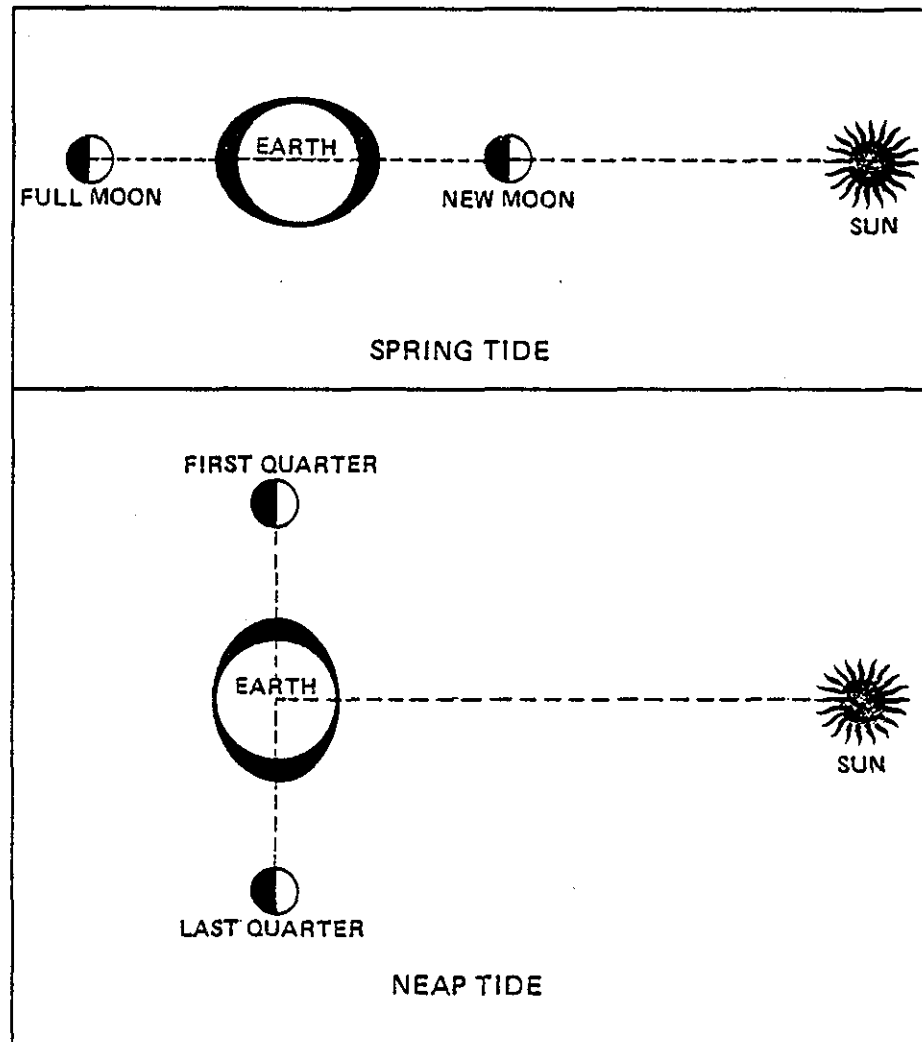
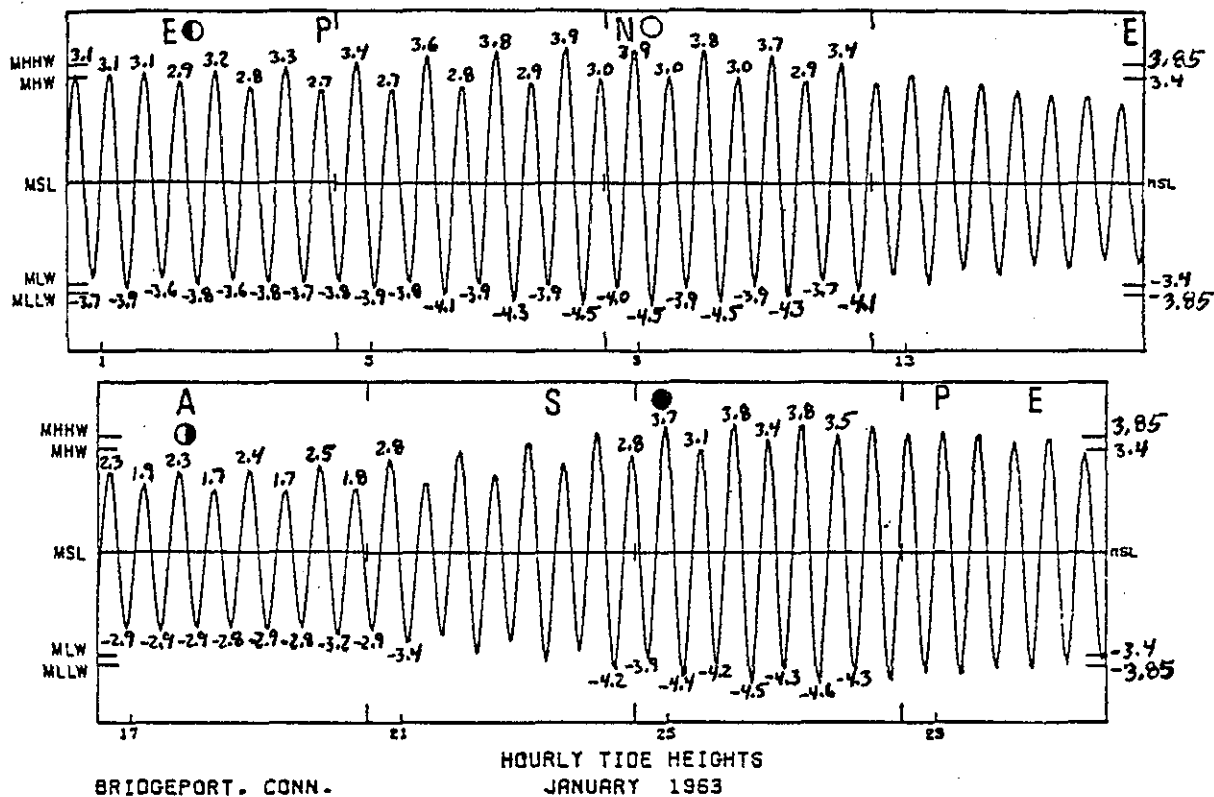


Figure 1. Lunar and solar tidal effects

FIGURE 2

PREDICTED ASTRONOMICAL TIDE HEIGHT
BRIDGEPORT, CONNECTICUT
JANUARY 1963



Letters and symbols above the curves are: E = Moon above Equator; P = Moon in perigee; A = Moon in apogee; N = Moon farthest north of Equator; S = Moon farthest south of Equator; ○ = Moon in first quarter; ◐ = Moon in third quarter; ○ = full Moon; ● = new Moon.

level and the predicted low tide as little as 1.5 feet or as much as 5.5 feet below local mean sea level. The National Ocean Survey (NOS) bases tide predictions for West Central Connecticut on detailed calculations for Bridgeport Harbor. The range of tide from mean low water to mean high water at most locations on the West Central Connecticut Coast is about the same as that at Bridgeport (See Table 1). Estimated maximum and minimum tide ranges for various locations on the Connecticut coast have been computed by adjusting the values for Bridgeport by the ratio of the mean tide range at the location of interest to the mean tide range in Bridgeport Harbor. These are also shown in the table.

c. Tidal Datum Planes

Because of the continual variation in water level due to the tides, several reference planes, called tidal datums, have been defined to serve as a reference zero for measuring elevations. The most fundamental of these is Mean Sea Level, abbreviated as MSL. Mean sea level is defined as the arithmetic mean of hourly water elevations observed over a specific 19-year metonic cycle (the National Tidal Datum Epoch). The epoch currently being analyzed by the NOS for mean sea level determination in the United States is 1960-78. Sea level is rising with respect to the land along most of the U.S. coast. Therefore the sea level determination is revised at intervals of about 25 years.

Mean sea level is defined only for explicit locations where suitable tide records are available. A reference level which can be used as a zero in elevation measurements even where no tide records are available is needed for mapping and many other applications. This reference is provided by the National Geodetic Vertical Datum of 1929 (NGVD). This datum was established by overland geodetic surveys with the intention of having the Geodetic Vertical Datum coincide with local mean sea level at 25 U.S. and Canadian tide stations. Geodetic surveys from the coasts have been used to carry this datum to a network of bench marks covering the United States. Because of land subsidence and rising sea levels, the NGVD is, today, lower than the MSL most everywhere in the United States. At Bridgeport, the National Ocean Survey's present official mean sea level, based on tide gage records, is about 0.7 ft. NGVD.

A third tidal datum, widely used by coastal engineers along the Atlantic coast, is mean low water (MLW). Mean low water is defined as the arithmetic mean of low water heights observed over a specific 19-year metonic cycle (the National Tidal Datum Epoch). Like mean sea level, mean low water is properly defined only for specific tide gage locations. Mean low water is a useful datum for hydrographic surveys where it is the minimum water depths that are most critical for navigation. Unfortunately MLW is often used for land surveys in the coastal region where MSL or NGVD would be more appropriate.

Computed similarly to MLW, mean high water (MHW) is the average high water level. Many times MSL is approximated by taking the average of MLW and MHW. This datum is referred to as mean tide level (MTL). When only spring tides are considered mean spring high and low waters can be computed (MHWS and MLWS).

TABLE 1
Astronomic Tide Ranges
Bridgeport and West Central Connecticut Coast

<u>Location</u>	<u>Mean Tide*</u> <u>Range</u> <u>(feet)</u>	<u>Mean</u> <u>Spring Tide*</u> <u>Range</u> <u>(feet)</u>	<u>Estimated</u> <u>Maximum Tide</u> <u>Range</u> <u>(feet)</u>	<u>Estimated</u> <u>Minimum Tide</u> <u>Range</u> <u>(feet)</u>
New Haven Harbor (entrance)	6.2	7.1	9.8	2.6
New Haven (city dock)	6.0	6.9	9.4	2.5
Milford Harbor	6.6	7.6	10.4	2.7
Stratford (Housatonic River)	5.5	6.3	8.7	2.3
Bridgeport	6.8	7.7	10.7**	2.8**
Black Rock Harbor (entrance)	6.9	7.9	10.9	2.8
Saugatuck River (entrance)	7.0	8.0	11.0	2.9

Notes: *Mean and mean spring tide range data obtained from the "Tide Tables 1987, High and Low water Predictions" by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey (NOS).

** Actual value, based upon 19 year Metonic tide cycle. Taken from CERC publication entitled "Tides and Tidal Datums in the U.S.", SR No. 7, 1981.

Tidal datum information for Bridgeport Harbor is presented on figure 3 and table 2. These data were compiled using currently available preliminary NOS tidal benchmark data for Bridgeport Harbor (1960-78 tidal

epoch) along with the CERC report entitled "Tides and Tidal Datums in the United States", SR No. 7, 1981. Tidal datum information throughout the study area for the 1922-40 tidal epoch is shown on Plate 3. Final NOS data for the 1960-78 epoch, when available, is not expected to show any significant difference from the preliminary results in Table 2 and Figure 3. Tidal datums on the profile (Plate 3) will be revised when NOS data is finalized.

TABLE 2

BRIDGEPORT HARBOR
TIDAL DATUM PLANES

	<u>Tide Level</u> (ft. NGVD)
Maximum Astronomic High Water	6.4
Mean Spring High Water (MHWS)	4.6
Mean High Water (MHW)	4.1
Minimum Astronomic High Water	1.9
Mean Tide Level (MTL)	0.7
National Geodetic Vertical Datum (NGVD)	0.0
Maximum Astronomic Low Water	-0.8
Mean Low Water (MLW)	-2.7
Mean Spring Low Water (MLWS)	-3.1
Minimum Astronomic Low Water	-4.8

2. METEOROLOGICAL FACTORS

a. Storm Types

Two distinct types of storms, known as tropical and extratropical cyclones, which can produce above normal water levels, must be recognized in studying coastal problems in New England.

(1) Tropical Cyclones

Tropical cyclones form in a warm moist air mass over a tropical ocean. The air mass is nearly uniform in all directions from the storm center; surface winds spiral inward from all directions. The air rises in a ring near the storm center. In the actual center, the air often descends, producing a cloud free eye. The temperature of the rising air is lowered because of the reduced pressure. Condensation occurs because of the decreased temperature. This supplies the latent heat of condensation to the air and intensifies the vertical motion, thus drawing more surface air into the storm. The energy for the storm is provided by the latent heat of condensation. When the maximum wind speed in a tropical cyclone exceeds 75 MPH (64 knots), it is called a hurricane. Although the hurricane structure is actually quite complex, it is useful for many purposes

to think of the hurricane as a circularly symmetric vortex imbedded in a flowing stream. When considered in this manner, the wind velocity at any position can be estimated as the sum of a rotating windfield in which the velocity depends only on the distance from the center and a uniform current which carries the storm along. It should be recognized this estimate is only an approximation to a more complex reality. The highest wind velocities occur at points to the right of the hurricane center where the spiral wind movement and forward motion of the storm are in the same direction. The maximum wind speeds in a hurricane may occur less than 10 miles from the storm center and rarely more than 30 miles from the center. The organized wind field may not extend more than 300 to 500 miles from the storm center. Because of the small size of tropical cyclones and the low density of weather observations over the sea during stormy conditions, the surface wind field is never recorded in much detail and the method of estimating the wind velocity just described is generally more accurate than interpolation between available observations. Atmospheric pressure falls rapidly as the center of the hurricane approaches and as the velocity of the wind increases. Usually the barometric low is about two inches below the normal sea level pressure of 30 inches.

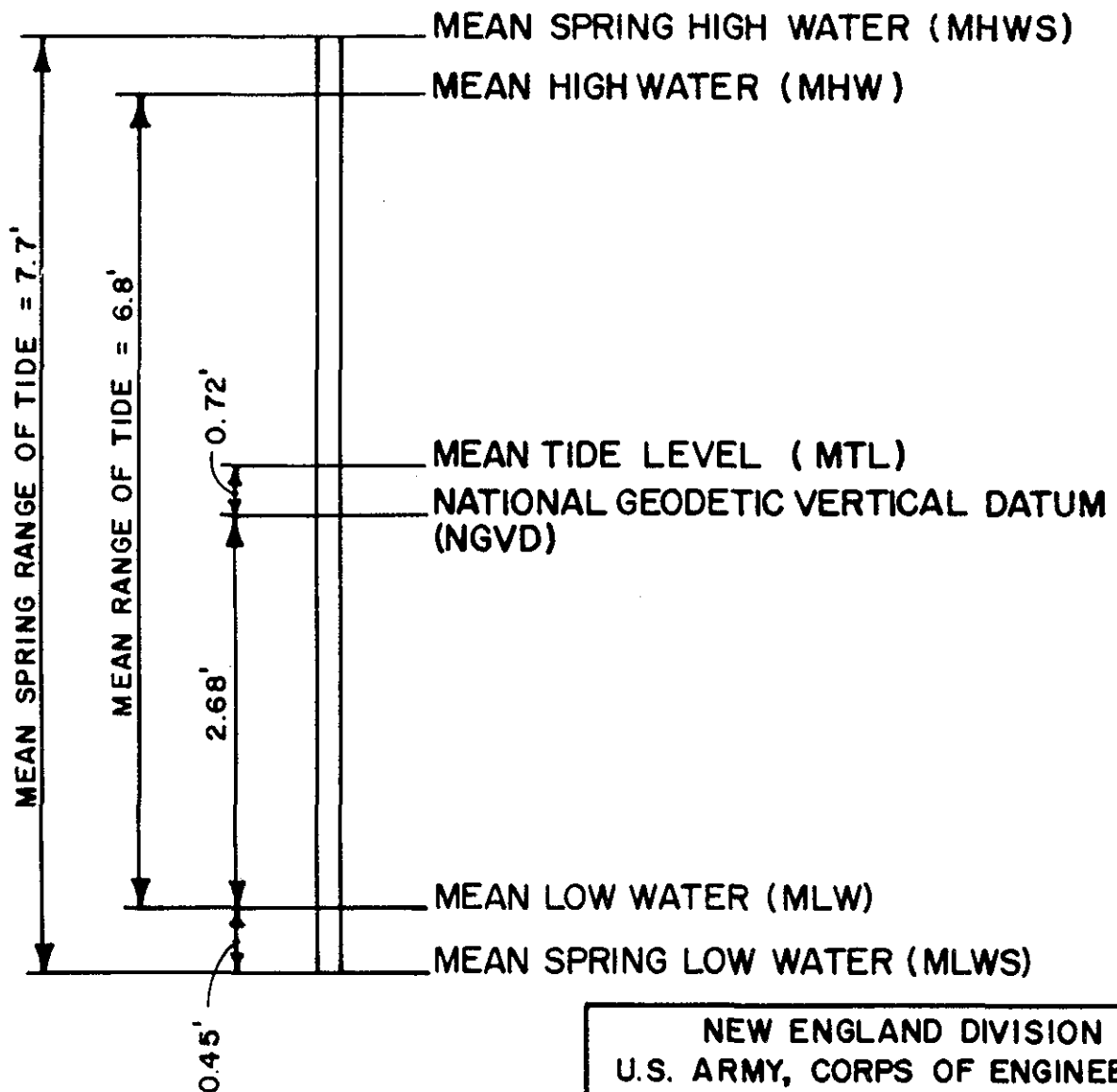
The type of storm which affects the area most severely is the hurricane. Most of the hurricanes that have affected the eastern coast of North America have formed either near the Cape Verde Islands off the African coast, or in the Western Caribbean Sea. Cape Verde hurricanes move westerly for a number of days with a forward speed of about 10 mph and generally, after reaching the Middle Atlantic Ocean, recurve northerly and then easterly. Frequently they cross the West Indies, sometimes striking the eastern coast of the United States between Key West, Florida, and Cape Cod, Massachusetts. After recurving, the storms usually increase their forward speed to a rate of 25 to 30 miles per hour and occasionally to speeds of 40 to 60 mph. The hurricanes which form in the Caribbean Sea generally move in a northerly direction and strike either the Gulf or the southeastern shores of the United States. The hurricanes that most severely affect the study area usually approach from the south after recurving east of Florida and skirting the Middle Atlantic States. The tracks of recent major hurricanes are shown on Figure 4. "Diane" was not a hurricane when it passed New England, having been downgraded to a tropical storm after landfall in North Carolina. However, it did produce record riverine flooding in many areas and was deemed important enough to be included on the figure.

The location of the storm track relative to a coastal community influences the magnitude of the storm's effect. As hurricanes and other low pressure systems in the northern hemisphere rotate in a counterclockwise direction, the winds will be highest and southerly if the storm center passes west of a community. On the east side of the storm track, the components affecting a surge, consisting of the forward speed of the storm, the high circulating hurricane winds and low barometric pressure,

FIGURE 3

TIDAL DATUM PLANES BRIDGEPORT HARBOR, CONNECTICUT

(BASED UPON NATIONAL
OCEAN SURVEY TIDAL
BENCHMARK DATA
FOR 1960-78 TIDAL EPOCH)



NEW ENGLAND DIVISION
U.S. ARMY, CORPS OF ENGINEERS
WALTHAM, MASS. SEPTEMBER 1987

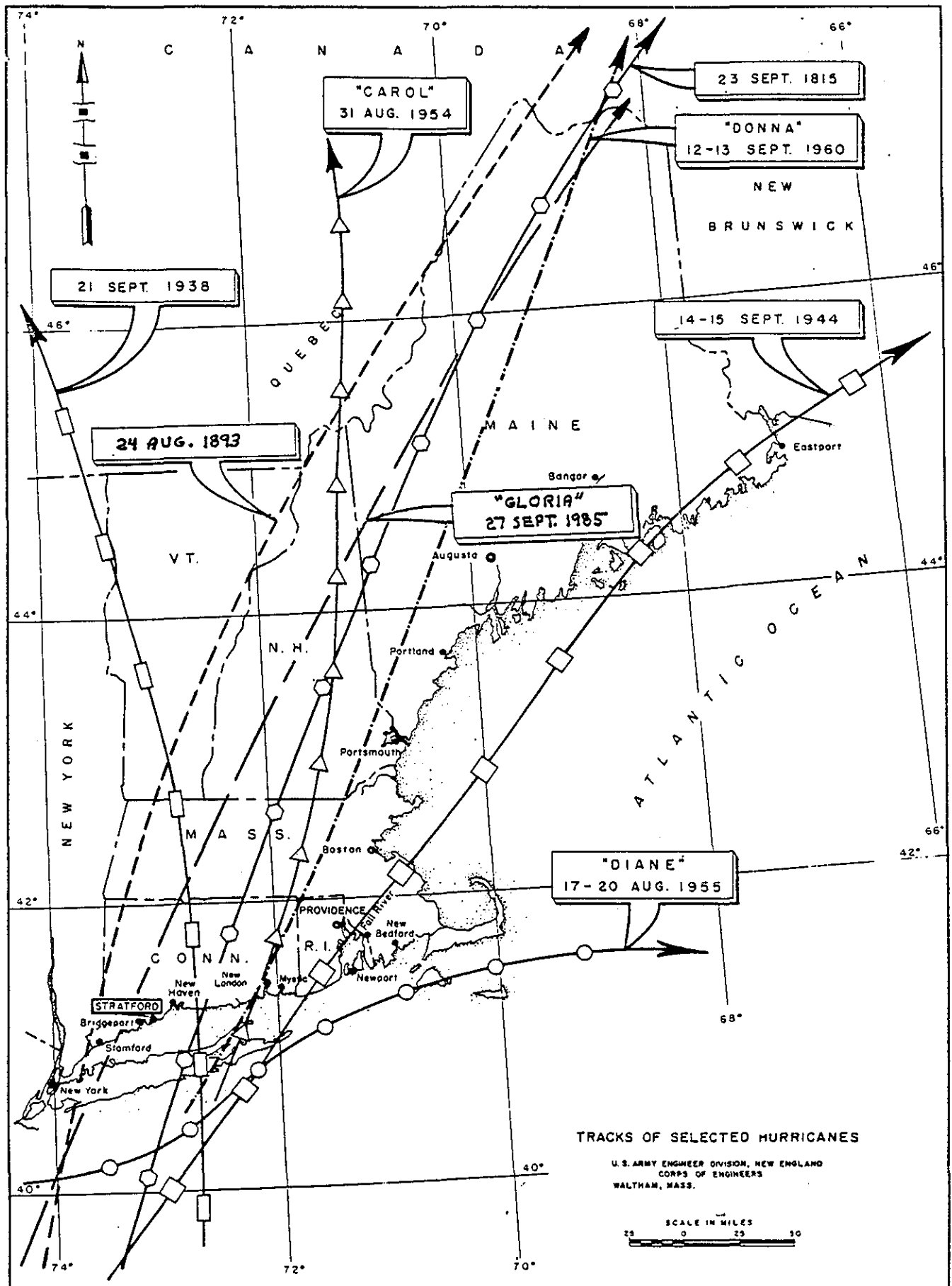


FIGURE 4

are additive. Such conditions may cause abnormally high tides and waves that are often intensified at the heads of coves and bays. On the west side of the storm center, however, the counterclockwise rotation of the storm produces northerly winds which are generally in opposition to the storm movement. The resultant wind velocities are subtractive and usually smaller than those experienced on the east side where the components are additive.

Another characteristic of a hurricane is the heavy rainfall that usually accompanies the storm. At the edge of the disturbance rainfall is light, normally in the form of showers. As the center approaches, the showers increase in frequency and intensity, becoming heavy to excessive near the eye. The heaviest rain usually falls ahead of the eye, driving torrentially from spiral bands of clouds that sometimes produce nearly two inches of rain per hour.

It is not yet possible to predict with a high degree of reliability whether the track of a hurricane, still several hundred miles away, may either hit or miss New England, or pass to the west or east of a community. The National Weather Service tracking season is from about 15 June to 15 November. Although it is possible for hurricanes to occur in most months, the major hurricanes of this century that have caused tidal flooding in the Sound have occurred in August or September. Because of the enormous energy associated with hurricanes, the highest abnormal tide can occur during any part of the predicted tide cycle, either high, low, or mean tides.

(2) Extratropical Cyclones

The most frequently occurring type of cyclone in New England is the extratropical variety. Low pressure centers frequently form or intensify on the polar front just off the coast of Georgia or the Carolinas and move northeastward more or less parallel to the coast. When the low pressure center passes a short distance southeast of Cape Cod the highest wind speeds over New England are generally from the northeast. For this reason, these storms are often called "nor'easters" in this region, even though the storm centers are generally moving from the south or the southwest. The local wind direction over the sound may vary from east to slightly west of north. Winds from this quadrant are not totally directed toward the shore in the study area and may not be accompanied by the largest waves and above normal water levels. Extratropical cyclones taking a more inland track may produce higher waves and water levels in the study area because winds during these storms, although not usually as high, are coming from the southeast over the open ocean. Frequently these storms are locally referred to as "southeasters". Figure 5 shows mean tracks of extratropical storms and resultant maximum wind direction.

The extratropical cyclone forms along the boundary between a continental air mass, generally one which has recently been in equilibrium with the cold dry planes of Western Canada, and a marine air mass which has spent several days over the warm moist Atlantic Ocean. The energy of the extratropical cyclone is derived from the temperature contrast between the cold and warm air masses. As a result of the thermal difference between these air masses, the marine air mass, generally southeast of the polar front, rides up over the colder air mass to the northwest. The moist air mass is cooled by the reduction of pressure and condenses, forming rain or snow. The latent heat of condensation acts to further warm the air and increases the thermal gradient across the front. The polar front is called a warm front in any region in which the warm air is advancing along the ground, and a cold front where the cold air is advancing. The minimum pressure generally occurs at the junction of the cold and warm fronts. This juncture of the cold and warm air masses may be compared to the crest of a wave on the water. The wave travels through the water at a much greater speed than any water particles. The low pressure center in the extratropical storm can, likewise, travel along the polar front with a greater speed than any of the winds in the system. The wind speed and storm speed in this type of storm are not closely related. The organized circulation pattern associated with this type of storm may extend for 1000 to 1500 miles from the storm center. The wind field in an extratropical cyclone is generally asymmetric with the highest winds in the north or northeastern quadrant. These winds are generally blowing from the northeast, north or northwest, while the storm center is moving toward the northeast.

No reasonably simple and usefully accurate method of describing the wind field in an extratropical cyclone as a function of the distance and direction from the storm center is known. Interpolation or extrapolation from available observations is generally satisfactory provided one considers data from only one air mass. That is, the interpolation or extrapolation must not cross a front.

Extratropical cyclones in New England have been recorded in the history of the region from the time of the first settlers. These storms occur most frequently during the autumn, winter and spring months. Although the winds and surges accompanying the storm are not as great as hurricanes, they do pose a constant threat to the coastal communities of the Sound.

During an extratropical storm the highest abnormal tides usually occur within one hour of the time of the predicted high tide. The most severe coastal storms have occurred in February, March, November and December.

b. Generation of Waves by the Wind

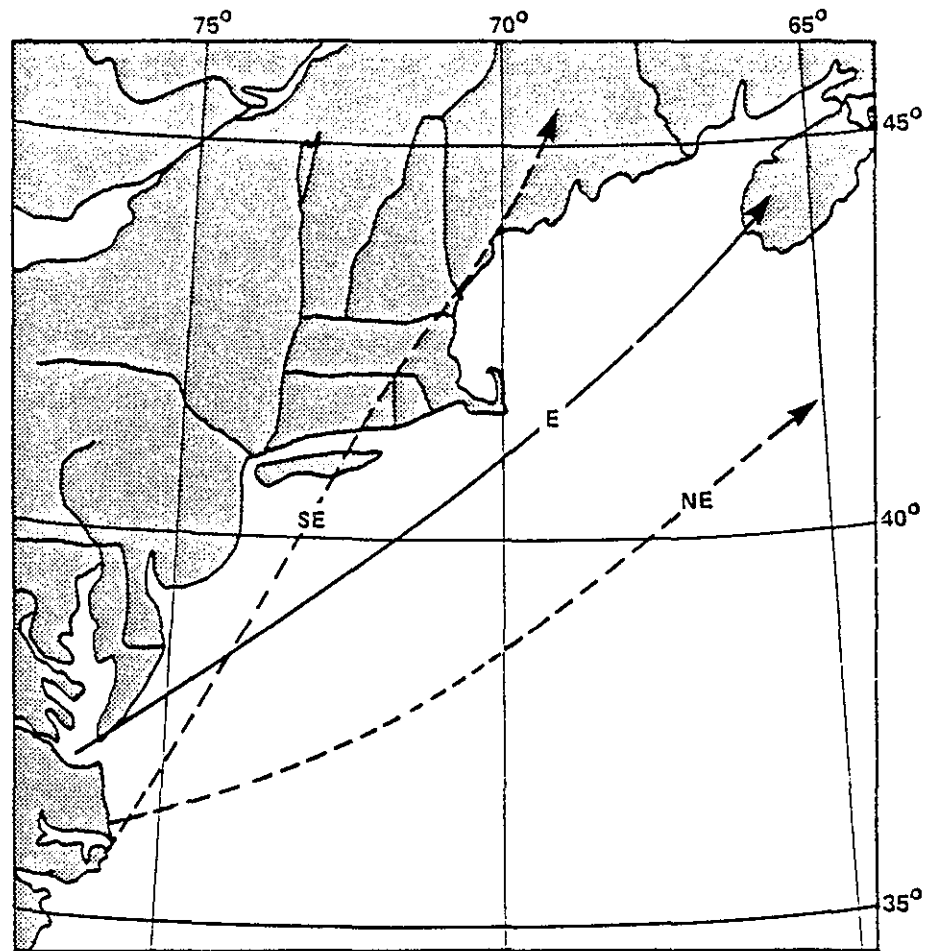


Figure 5. Mean tracks of surge-producing extratropical storms

When a steady wind starts to blow over a calm body of water, waves are developed. The wave height and period increases with the wind speed, the duration of the wind and the distance (fetch) over which the wind blows. The exact details of the process are not yet fully identified, but the foregoing statements are universally accepted. The wave height and period may ultimately reach a maximum with duration or fetch of the wind. Hurricane winds generate gigantic waves. The ultimate size of the waves depends upon the force and duration of the wind and the distance the wave travels. Driven by hurricane winds, the breaking waves will run up on a shelving beach or overtop vertical structures well above the actual still-water height, so that reports of wave and flood damage from 5 to 25 feet above stillwater level are not uncommon. The rise of the tide due to the storm amounts to only one or two feet in the open ocean while its magnitude can reach six to ten feet or more at coastal points. The maintenance of wave gages near the coasts during storms is difficult, and it is nearly always necessary to use estimates of wave conditions based on the available meteorological data (wave "hindcasts") to obtain a substantial part of the wave estimates needed in planning engineering activity in the coastal zone.

(1) Deep Ocean Wave Hindcasts

The Corps of Engineers Waterways Experiment Station has conducted wave hindcasting studies along the Atlantic coast. Their studies simulated the generation of waves over the open ocean for the period 1956 through 1975 and routed them shoreward to a 10 meter depth. Figure 6 shows the location of the nearshore stations, station 41 being near the mouth of Long Island Sound. Table 3 shows the percent occurrence of wave height and period by direction from 11 to 191 degrees azimuth (approximately north to south, respectively). The shoreline angle is measured clockwise from north, while the angle of wave approach is measured counter clockwise from the shoreline. Azimuth of wave approach is taken clockwise from north. The largest significant wave, 4.08 m (13.38) ft. with longest period (greater than 11 sec.) comes from 101-131 degrees azimuth or approximately the east to southeast direction, with the greatest percentage of waves coming from 161-191 degrees azimuth or about the south-southeast to south with a maximum height of 1.68m (5.51 ft.) at a period of about 6.5 seconds. Table 4 presents similar information for all directions. Figure 7 graphically presents the percent occurrence of waves by direction and height relative to shoreline angle. Alphabetic direction descriptors have been annotated for easy reference. Tables 5 and 6 present mean and largest significant waves by month and year, July and August appearing to be lower wave energy months.

Although these deep ocean waves from the east-northeast through south-southeast can affect the study area, locally generated waves within Long Island Sound generated from southwesterly to southeasterly winds can cause a much greater threat due to the relatively long fetch available in

TABLE 3

161-191 Degrees Azimuth*

STATION 41 20 YEARS WAVE APPROACH ANGLE(DEGREES)= 0. - 29.9
 SHORELINE ANGLE = 11.0 DEGREES AZIMUTH
 WATER DEPTH = 10.00 METRES
 PERCENT OCCURRENCE(X1000) OF HEIGHT AND PERIOD BY DIRECTION

HEIGHT(METRES)	PERIOD(SECONDS)										TOTAL
	0.0- 2.9	3.0- 3.9	4.0- 4.9	5.0- 5.9	6.0- 6.9	7.0- 7.9	8.0- 8.9	9.0- 9.9	10.0- 10.9	11.0- LONGER	
0.0 - 0.49	3569	7811	5799	2489	1324	1546	87				22625
0.50 - 0.99		277	2116	1353	525	396	42	3	15	5	4757
1.00 - 1.49			5	99	104	8	3		1		223
1.50 - 1.99					1						0
2.00 - 2.49											0
2.50 - 2.99											0
3.00 - 3.49											0
3.50 - 3.99											0
4.00 - 4.49											0
4.50 - 4.99											0
5.00 - GREATER											0
TOTAL	3569	8088	7920	3941	1954	1950	132	6	16	5	0

AVERAGE HS(M) = 0.30 LARGEST HS(M) = 1.68 ANGLE CLASS % = 27.6

131-161 Degrees Azimuth

STATION 41 20 YEARS WAVE APPROACH ANGLE(DEGREES)= 30.0 - 59.9
 SHORELINE ANGLE = 11.0 DEGREES AZIMUTH
 WATER DEPTH = 10.00 METRES
 PERCENT OCCURRENCE(X1000) OF HEIGHT AND PERIOD BY DIRECTION

HEIGHT(METRES)	PERIOD(SECONDS)										TOTAL
	0.0- 2.9	3.0- 3.9	4.0- 4.9	5.0- 5.9	6.0- 6.9	7.0- 7.9	8.0- 8.9	9.0- 9.9	10.0- 10.9	11.0- LONGER	
0.0 - 0.49	900	1358			2375	2529	3054	143	735	219	11313
0.50 - 0.99		624	1702	396	196	713	747	189	338	462	5367
1.00 - 1.49			121	715	395	508	186	71	130	44	2170
1.50 - 1.99			1	18	215	386	154	59	15	3	851
2.00 - 2.49					41	174	88	29	5	6	343
2.50 - 2.99						17	18	20	5		68
3.00 - 3.49							1	8	1	3	17
3.50 - 3.99											1
4.00 - 4.49											0
4.50 - 4.99											0
5.00 - GREATER											0
TOTAL	900	1982	1824	1129	3222	4327	4248	519	1230	737	0

AVERAGE HS(M) = 0.60 LARGEST HS(M) = 3.57 ANGLE CLASS % = 20.1

101-131 Degrees Azimuth

STATION 41 20 YEARS WAVE APPROACH ANGLE(DEGREES)= 60.0 - 89.9
 SHORELINE ANGLE = 11.0 DEGREES AZIMUTH
 WATER DEPTH = 10.00 METRES
 PERCENT OCCURRENCE(X1000) OF HEIGHT AND PERIOD BY DIRECTION

HEIGHT(METRES)	PERIOD(SECONDS)										TOTAL
	0.0- 2.9	3.0- 3.9	4.0- 4.9	5.0- 5.9	6.0- 6.9	7.0- 7.9	8.0- 8.9	9.0- 9.9	10.0- 10.9	11.0- LONGER	
0.0 - 0.49	682	1324	420	47	562	1721	1327	124	27	1601	7835
0.50 - 0.99		256	1415	807	231	1972	1627	237	71	186	7007
1.00 - 1.49			32	448	359	623	691	77	66	46	2381
1.50 - 1.99				13	162	473	265	30	4	11	995
2.00 - 2.49					41	244	224	23	3	1	536
2.50 - 2.99						22	102	51	5		180
3.00 - 3.49							6	22	11		39
3.50 - 3.99								3	6		9
4.00 - 4.49										3	3
4.50 - 4.99											0
5.00 - GREATER											0
TOTAL	682	1580	1867	1315	1355	5094	4442	567	230	1848	0

AVERAGE HS(M) = 0.72 LARGEST HS(M) = 4.08 ANGLE CLASS % = 19.0

* Wave approach angle expressed in degrees clockwise from north

WAVE INFORMATION STUDY
LOCATION MAP

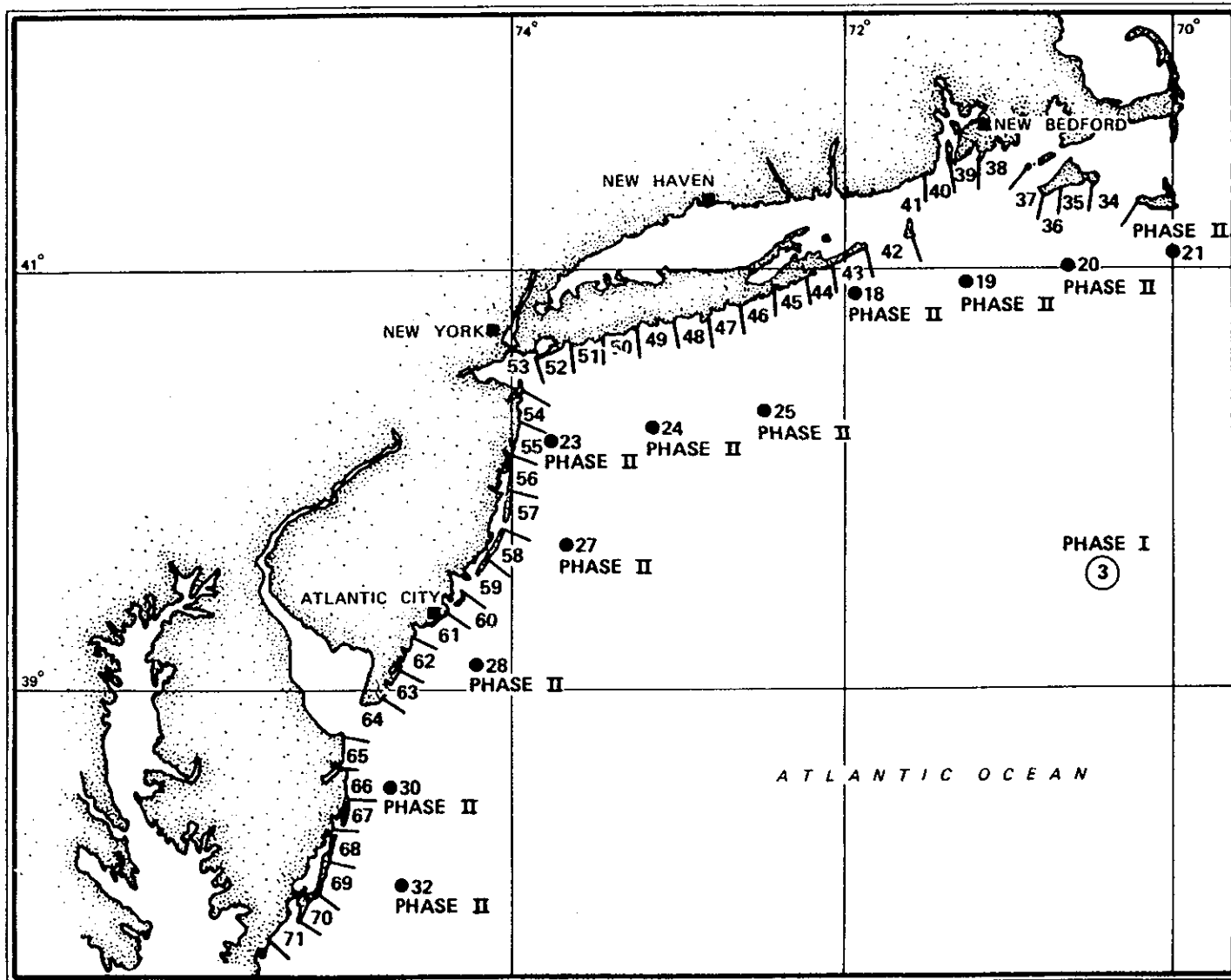


FIGURE 6

TABLE 3 (cont.)

71-101 Degrees Azimuth

STATION 41 20 YEARS WAVE APPROACH ANGLE(DEGREES)= 90.0 - 119.9
 SHORELINE ANGLE = 11.0 DEGREES AZIMUTH
 WATER DEPTH = 10.00 METRES
 PERCENT OCCURRENCE(X1000) OF HEIGHT AND PERIOD BY DIRECTION

HEIGHT(METRES)	PERIOD(SECONDS)											TOTAL
	0.0- 2.9	3.0- 3.9	4.0- 4.9	5.0- 5.9	6.0- 6.9	7.0- 7.9	8.0- 8.9	9.0- 9.9	10.0- 10.9	11.0- LONGER		
0.0-0.49	569	1095	1451	2162	770	82	5	.	.	3		6137
0.5-0.99	.	5	25	111	126	128	355	.	.	.		420
1.0-1.49	.	.	1	3	15	41	11	11	.	.		106
1.5-1.99	8	10	5	1	3	.		26
2.0-2.49	1	.	.	.		15
2.5-2.99		1
3.0-3.49		0
3.5-3.99		0
4.0-4.49		0
4.5-4.99		0
5.0-5.49		0
5.5-5.99		0
6.0-6.49		0
6.5-6.99		0
7.0-7.49		0
7.5-7.99		0
8.0-8.49		0
8.5-8.99		0
9.0-9.49		0
9.5-9.99		0
10.0-10.49		0
10.5-10.99		0
11.0-11.49		0
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30.5-30.99		0
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32.5-32.99		0
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35.5-35.99		0
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37.5-37.99		0
38.0-38.49		0
38.5-38.99		0
39.0-39.49		0
39.5-39.99		0
40.0-40.49		0
40.5-40.99		0
41.0-41.49		0
41.5-41.99		0
42.0-42.49		0
42.5-42.99		0
43.0-43.49		0
43.5-43.99		0
44.0-44.49		0
44.5-44.99		0
45.0-45.49		0
45.5-45.99		0
46.0-46.49		0
46.5-46.99		0
47.0-47.49		0
47.5-47.99		0
48.0-48.49		0
48.5-48.99		0
49.0-49.49		0
49.5-49.99		0
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53.0-53.49		0
53.5-53.99		0
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57.5-57.99		0
58.0-58.49		0
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60.5-60.99		0
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80.5-80.99		0
81.0-81.49		0
81.5-81.99		0
82.0-82.49		0
82.5-82.99		0
83.0-83.49	.	.										

TABLE 4

STATION 41 20 YEARS FOR ALL DIRECTIONS
SHORELINE ANGLE = 11.0 DEGREES AZIMUTH
WATER DEPTH = 10.00 METRES
PERCENT OCCURRENCE (X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS

HEIGHT (METRES)	PERIOD (SECONDS)										TOTAL
	0.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-10.9	11.0- LONGER	
10.0	572	1158	767	470	503	587	447	26	76	182	4788
9.5	.	116	526	266	107	102	264	45	45	65	1750
9.0	.	.	16	12	38	102	91	100	19	9	486
8.5	.	.	.	3	8	35	43	5	5	1	205
8.0	3	12	.	.	.	22
7.5	0
7.0	0
6.5	0
6.0	0
5.5	0
5.0	0
4.5	0
4.0	0
3.5	0
3.0	0
2.5	0
2.0	0
1.5	0
1.0	0
0.5	0
0.0	0
TOTAL	572	1274	1309	865	743	1162	887	109	143	257	58440

AVE HS (M) = 0.35 LARGEST HS (M) = 4.08 TOTAL CASES = 58440

FIGURE 7

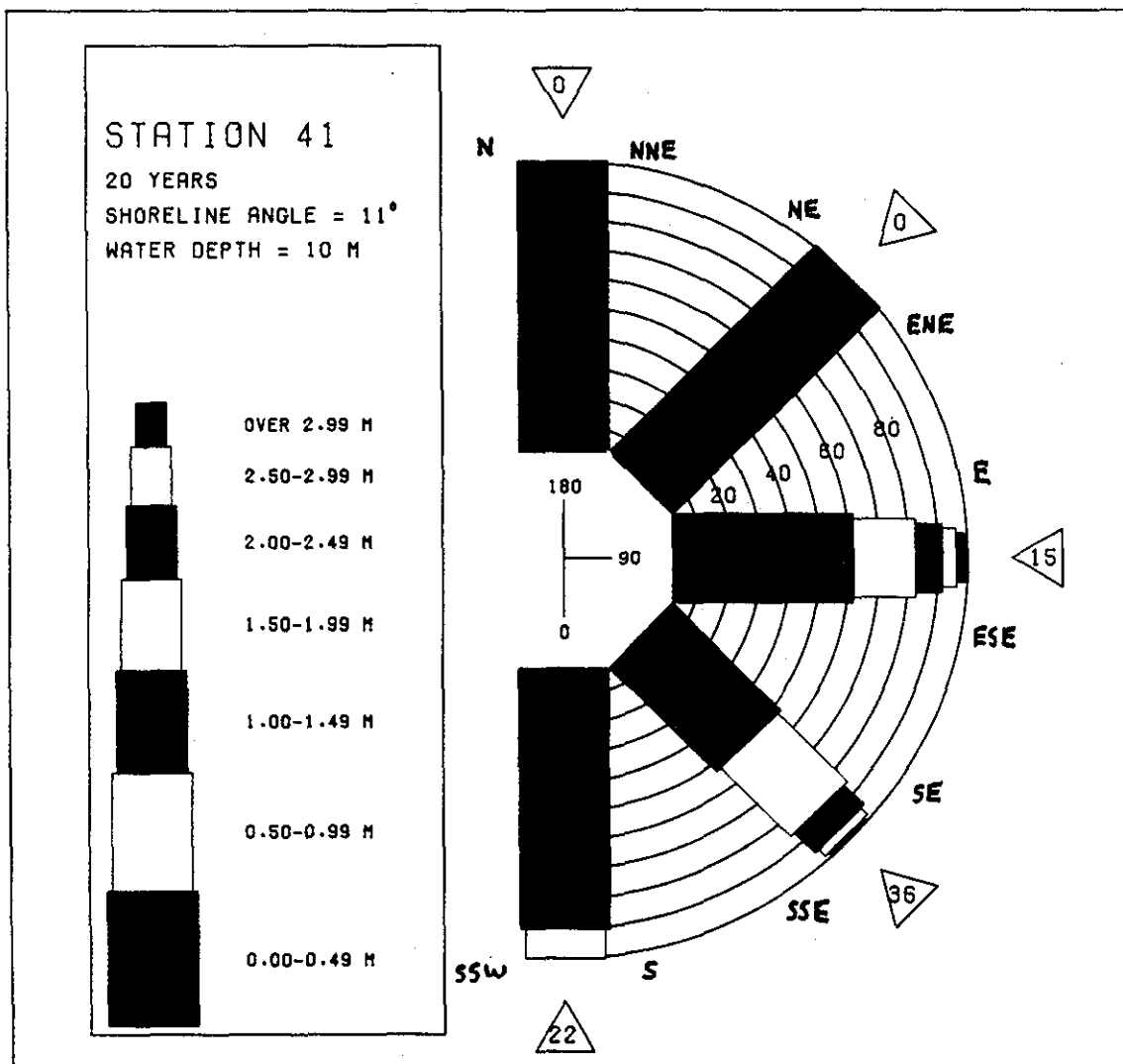


TABLE 5

MEAN HS(METRES) BY MONTH AND YEAR

STATION 41

MONTH

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
YEAR													
1956	0.2	0.3	0.3	0.4	0.3	0.5	0.3	0.2	0.4	0.7	0.4	0.3	0.4
1957	0.2	0.2	0.2	0.4	0.2	0.3	0.3	0.3	0.3	0.4	0.5	0.7	0.3
1958	0.6	0.3	0.7	0.5	0.4	0.6	0.3	0.3	0.2	0.7	0.4	0.2	0.4
1959	0.3	0.2	0.4	0.3	0.1	0.2	0.4	0.3	0.2	0.7	0.9	0.3	0.4
1960	0.2	0.5	0.3	0.4	0.3	0.8	0.4	0.3	0.3	0.3	0.3	0.2	0.3
1961	0.3	0.4	0.3	0.4	0.3	0.4	0.3	0.2	0.5	0.4	0.2	0.2	0.3
1962	0.3	0.4	0.3	0.5	0.2	0.2	0.2	0.3	0.2	0.3	0.6	0.8	0.3
1963	0.4	0.3	0.4	0.3	0.4	0.2	0.2	0.3	0.5	0.2	0.6	0.2	0.3
1964	0.4	0.4	0.3	0.3	0.2	0.2	0.3	0.3	0.6	0.3	0.3	0.4	0.3
1965	0.3	0.3	0.3	0.2	0.2	0.3	0.3	0.4	0.4	0.3	0.3	0.5	0.3
1966	0.2	0.2	0.3	0.4	0.3	0.4	0.3	0.3	0.5	0.2	0.8	0.4	0.3
1967	0.3	0.4	0.5	0.2	0.4	0.4	0.2	0.3	0.3	0.3	0.2	0.3	0.3
1968	0.3	0.1	0.4	0.2	0.4	0.6	0.6	0.5	0.4	0.2	0.4	0.3	0.4
1969	0.4	0.2	0.3	0.4	0.4	0.3	0.3	0.5	0.4	0.2	0.6	0.4	0.4
1970	0.1	0.5	0.3	0.4	0.6	0.5	0.3	0.2	0.2	0.5	0.4	0.3	0.4
1971	0.2	0.4	0.3	0.4	0.6	0.6	0.4	0.3	0.3	0.4	0.2	0.2	0.4
1972	0.3	0.5	0.7	0.2	0.6	0.5	0.2	0.2	0.3	0.7	0.3	0.4	0.4
1973	0.3	0.3	0.4	0.4	0.5	0.4	0.3	0.2	0.2	0.3	0.4	0.8	0.4
1974	0.3	0.3	0.9	0.6	0.3	0.4	0.5	0.2	0.2	0.1	0.3	0.5	0.4
1975	0.3	0.3	0.4	0.2	0.2	0.5	0.4	0.2	0.2	0.2	0.3	0.9	0.3
MEAN	0.3	0.3	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.4	0.4	0.4	

TABLE 6

LARGEST HS(METRES) BY MONTH AND YEAR

STATION 41

MONTH

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
YEAR												
1956	2.5	1.8	2.0	2.8	1.2	1.1	1.5	1.2	2.1	2.0	2.0	1.9
1957	1.5	1.5	2.2	2.3	0.9	1.5	1.0	1.1	1.1	1.6	1.9	2.2
1958	2.7	3.0	3.3	2.3	1.4	1.4	0.8	1.4	1.7	2.6	2.4	2.0
1959	2.3	1.8	2.8	1.9	0.7	1.0	2.2	1.1	0.9	3.1	2.0	2.2
1960	1.9	2.8	2.2	2.0	1.2	1.6	2.3	1.5	2.4	2.0	1.2	2.0
1961	2.0	2.7	2.6	2.4	2.5	1.2	1.1	1.2	3.5	1.1	1.6	1.9
1962	1.8	2.1	2.9	2.3	0.9	1.0	0.8	1.4	2.0	2.4	2.8	2.6
1963	2.3	2.1	2.3	1.5	2.2	1.3	1.0	1.8	1.8	1.8	2.7	2.0
1964	2.6	2.8	1.8	1.6	1.0	0.8	1.6	1.7	2.1	1.4	2.4	1.9
1965	2.6	2.5	1.9	2.0	0.7	1.1	0.9	1.3	1.4	1.8	1.2	2.1
1966	2.9	2.0	1.8	2.0	1.2	2.0	1.4	0.9	2.5	1.0	2.5	2.3
1967	2.2	1.8	2.1	1.8	2.7	2.0	0.8	1.4	2.1	1.8	1.8	2.7
1968	2.4	1.0	2.9	1.7	2.8	1.8	0.9	0.9	1.3	1.6	2.9	2.1
1969	1.7	2.2	3.6	2.0	2.0	0.8	1.3	1.1	1.7	1.0	2.7	3.2
1970	1.5	3.0	1.7	2.4	1.5	1.1	0.9	1.4	1.1	2.5	2.2	3.2
1971	2.1	2.3	3.3	2.7	2.1	1.2	1.1	2.1	1.4	1.9	2.2	1.5
1972	1.2	4.1	2.9	1.9	2.0	2.7	0.7	0.9	2.9	2.5	2.7	3.4
1973	2.5	2.5	2.0	2.8	1.6	1.7	1.2	1.7	1.1	2.8	1.8	3.7
1974	2.1	2.3	3.1	2.2	2.0	1.4	1.2	1.1	1.7	0.9	1.7	3.5
1975	2.6	2.4	3.2	2.1	0.9	1.6	1.1	0.8	1.4	1.3	2.3	3.4

LARGEST HS(METRES) FOR STATION 41 = 4.1

the Sound, extreme hurricane winds generally coming from between the SW and SE. Locally generated waves were not part of the WES study. Therefore, wave height and period for these waves must be estimated based on wind speed, duration and fetch distance.

(2) Wind Data for Estimating Locally Generated Waves

An estimate of wind speed is one of the essential ingredients in any wave hindcasting effort. The most accurate estimate of winds at sea, which generate waves and propel them landward, is obtained by utilizing isobars of barometric pressure recorded during a given storm. However, actual recorded wind speed and direction data observed at a land based coastal meteorological station can serve as a useful guide when more locally generated waves and currents are of interest. The disadvantage with using land based wind records is that they may not be totally indicative of wind velocities at the sea-air interface where the waves are generated. However, often they are the only available source of information and adjustments must be made to develop overwater estimates from the land based records.

The National Weather Service (NWS) recorded 13 complete years of hourly one-minute average wind speed and direction data at Bridgeport Municipal Airport in Stratford, Connecticut from 1949 through 1974. Bridgeport is the closest location to the study area for which relatively complete, systematically recorded, wind data are available. These wind speed data were then adjusted to a standard 33-foot observation height, and one-minute average wind speeds were converted to one-hour average wind speeds. Since Bridgeport Municipal Airport is almost directly adjacent to the ocean, no land-sea conversion was applied. However, a wind stability correction was made except between W and NW where fetches of interest are less than 10 miles. All adjustments were made in accordance with ETL 1110-2-305 on the subject of determining wave characteristics on sheltered waters. Utilizing these one-hour average wind data, the percent occurrence of wind direction and wind speed range has been computed. Since only on-shore winds are of interest, the wind directions utilized in this analysis have been limited to those between east-northeast (ENE) and northwest (NW). This analysis, the results of which are shown in Table 7, indicates that the principal onshore wind direction for wind speeds ≤ 5 mph is from the NW and, for wind speeds > 5 and ≤ 15 mph it is from the SW. Winds > 15 mph and ≤ 30 mph generally come from the NW to WNW. Winds exceeding 30 mph seem to come from the E and W to NW. The maximum average wind speed (10.2 mph) is from the WNW and the greatest maximum speed was 47.5 mph from the E. Overall average speed is 9.3 mph. The greatest percentage of wind speeds is shown to be > 10 and ≤ 15 mph.

Utilizing the above mentioned height adjusted data base, average wind speeds and resultant directions were computed over various durations with the other previously mentioned adjustments being made subsequently.

TABLE 7
 STRATFORD, CONNECTICUT
ADJUSTED HOURLY WIND OBSERVATIONS BETWEEN "ENE" AND "NW"
 (One-Hour Average Values)

Percent of Onshore Windspeed and Direction Observations (X 10)

Direction	Windspeed Range (MPH)							All Inclusive	Average Speed	Maximum Speed
	0-5	5-10	10-15	15-20	20-25	25-30	Over 30			
ENE	10	18	27	10	5	2	0	73	9.5	41.9
E	10	19	28	9	5	2	1	74	9.6	47.5
ESE	7	15	16	4	2	0	0	45	9.3	36.9
SE	8	14	11	2	0	0	0	36	7.9	38.9
SSE	8	14	10	2	0	0	0	34	7.7	26.6
S	12	23	22	5	2	1	0	65	8.8	38.9
SSW	9	21	28	8	3	0	0	70	9.7	37.9
SW	16	39	55	12	4	1	0	126	9.3	32.8
WSW	13	39	49	13	5	1	0	120	9.7	44.1
W	14	36	46	14	8	2	1	120	9.4	36.3
WNW	13	27	44	17	11	4	1	117	10.2	36.3
NW	19	26	41	19	12	3	1	121	10.0	34.5
ENE-NW	139	291	377	115	57	16	4	1,000	9.3	47.5

NOTE: Windspeed ranges indicated include values greater than the lower limit and less than or equal to the higher limit

Annual maximum values were then determined for each onshore direction. The frequency of these annual values has been determined using a Pearson Type III distribution function with expected probability adjustment. The systematic record alone was used for all analyses. In some cases severe extratropical storm winds were identified as high outliers in a statistical test and sometimes high skewness were observed. These cause some inconsistency in the estimates which can best be accommodated by a graphical smoothing of the tabular data. All results are summarized in Table 8. It should be noted that frequency estimates are generally quite accurate for return periods up to twice the period of record, 26 years in this case. To obtain estimates of wind speed-duration relationships for a particular return period and direction, it is recommended that a graphical curve fitting analysis employing engineering judgment be conducted using the tabularized values. Figure 8 is an example of this technique for the WSW direction which may be a critical wave generation direction in the study area. Analysis of other directions is left to a potential user.

Additionally, wind speed persistence was determined on a directional basis. The resulting wind speed persistence data, shown on Table 9, for directions east-northeast through northwest, indicate the maximum number of consecutive hourly wind speed observations that occurred at or above a given speed from a particular direction. Data on Table 9 indicate an occurrence of winds in excess of 25 mph for five consecutive hours from the south. Three consecutive hourly values greater than 30 mph and five consecutive hourly values greater than 25 mph from the west-southwest are shown. The highest average wind speed listed is 47 mph from the E. Winds greater than 30 mph from the west for three consecutive hours are presented in the table. All this information demonstrates that high onshore winds can occur for extended periods of time in the study area. Lower speed winds seem to come mainly from the SSE with an increasingly westerly or easterly trend as the speed class increases.

TABLE 8

FREQUENCY OF ADJUSTED ANNUAL MAXIMUM WIND SPEEDS (MPH)
STRATFORD, CONNECTICUT
 (Based on 13 Years of Hourly Observations, 1949-1974)

Direction: ENE

<u>Duration</u> (hours)	<u>Expected Return Period (Years)</u>						
	<u>1</u>	<u>2</u>	<u>5</u>	<u>10</u>	<u>25</u>	<u>50</u>	<u>100</u>
1 min	24	33	41	46	52	58	64
1	19	27	33	37	42	47	52
3	18	24	27	29	32	35	37
8	16	22	24	25	26	27	28

Direction: E

Duration (hours)	Expected Return Period (Years)						
	<u>1</u>	<u>2</u>	<u>5</u>	<u>10</u>	<u>25</u>	<u>50</u>	<u>100</u>
1 min	25	36	46	52	60	67	74
1	20	29	37	42	48	54	60
3	17	26	33	38	45	50	55
8	15	22	29	33	40	46	52

Direction: ESE

Duration (hours)	Expected Return Period (Years)						
	<u>1</u>	<u>2</u>	<u>5</u>	<u>10</u>	<u>25</u>	<u>50</u>	<u>100</u>
1 min	22	31	36	41	46	51	56
1	18	25	29	33	37	41	45
3	13	21	24	26	27	28	29
8	13	19	22	24	27	29	31

Direction: SE

Duration (hours)	Expected Return Period (Years)						
	<u>1</u>	<u>2</u>	<u>5</u>	<u>10</u>	<u>25</u>	<u>50</u>	<u>100</u>
1 min	19	27	36	41	48	55	62
1	15	22	29	33	39	44	50
3	12	18	21	22	23	24	25
8	7	15	18	19	20	20	21

Direction: SSE

Duration (hours)	Expected Return Period (Years)						
	<u>1</u>	<u>2</u>	<u>5</u>	<u>10</u>	<u>25</u>	<u>50</u>	<u>100</u>
1 min	18	30	32	33	34	35	35
1	15	24	26	27	28	28	28
3	14	20	23	26	29	31	34
8	7	16	18	20	22	23	24

Direction: S

Duration (hours)	Expected Return Period (Years)						
	<u>1</u>	<u>2</u>	<u>5</u>	<u>10</u>	<u>25</u>	<u>50</u>	<u>100</u>
1 min	23	35	40	44	48	51	54
1	19	28	33	35	39	41	44
3	18	25	28	30	32	34	36
8	5	20	24	26	28	29	30

Direction: SSW

<u>Duration</u> (hours)	<u>Expected Return Period (Years)</u>						
	<u>1</u>	<u>2</u>	<u>5</u>	<u>10</u>	<u>25</u>	<u>50</u>	<u>100</u>
1 min	24	34	40	44	48	52	55
1	19	28	32	35	39	42	45
3	18	23	25	27	29	30	32
8	15	19	23	27	32	36	40

Direction: SW

<u>Duration</u> (hours)	<u>Expected Return Period (Years)</u>						
	<u>1</u>	<u>2</u>	<u>5</u>	<u>10</u>	<u>25</u>	<u>50</u>	<u>100</u>
1 min	22	32	37	39	42	45	47
1	18	26	30	32	34	36	38
3	18	22	26	30	35	39	43
8	13	20	23	24	26	27	29

Direction: WSW

<u>Duration</u> (hours)	<u>Expected Return Period (Years)</u>						
	<u>1</u>	<u>2</u>	<u>5</u>	<u>10</u>	<u>25</u>	<u>50</u>	<u>100</u>
1 min	17	35	45	51	59	65	71
1	14	29	36	41	47	52	57
3	15	24	30	34	40	44	48
8	13	22	27	29	33	36	38

Direction: W

<u>Duration</u> (hours)	<u>Expected Return Period (Years)</u>						
	<u>1</u>	<u>2</u>	<u>5</u>	<u>10</u>	<u>25</u>	<u>50</u>	<u>100</u>
1 min	19	35	41	44	47	49	52
1	15	29	33	35	38	40	42
3	12	26	30	31	33	34	35
8	10	22	25	27	28	29	30

Direction: WNW

<u>Duration</u> (hours)	<u>Expected Return Period (Years)</u>						
	<u>1</u>	<u>2</u>	<u>5</u>	<u>10</u>	<u>25</u>	<u>50</u>	<u>100</u>
1 min	24	36	41	43	46	49	51
1	19	29	33	35	38	39	41
3	17	26	29	30	32	33	34
8	15	22	25	27	29	30	31

Direction: NW

<u>Duration</u> (hours)	<u>Expected Return Period (Years)</u>						
	<u>1</u>	<u>2</u>	<u>5</u>	<u>10</u>	<u>25</u>	<u>50</u>	<u>100</u>
1 min	22	35	40	42	45	47	50
1	18	28	32	34	37	38	40
3	16	24	27	29	31	33	35
8	16	21	24	26	28	30	32

Waves generated during coastal storms are particularly potent as an erosive and flooding force. Therefore, it is useful to examine wind conditions occurring during past storms when estimating the severity of wave conditions. Table 10 presents available National Weather Service wind observations recorded between 1947 and 1975 at Bridgeport Airport during days of storm-induced tidal flooding. It can be seen that the strongest winds recorded on these dates generally occurred between north and east. The highest speed listed, 64.5 mph from the east, was recorded on 25 November 1950.

The most reliable data on experienced hurricane wind velocities in New England begin with the September 1938 hurricane. The maximum velocity in New England during this storm was a recorded gust of 186 mph at the Blue Hills observatory in Milton, Massachusetts, where a sustained 5-minute wind of 121 mph was also recorded. At other locations in southern New England, sustained 5-minute velocities ranging from 38 to 87 mph were experienced.

During the hurricane of 14 September 1944, a maximum gust of 109 mph was registered at Hartford, Connecticut. Sustained 5-minute velocities ranging from 33 to an estimated 85 mph were recorded at a number of locations between New York City and Block Island, Rhode Island, during this same hurricane.

TABLE 9

WINDSPEED PERSISTENCE
STRATFORD, CONNECTICUT

Maximum Duration, Hours and (Average Windspeed, MPH)

Direction	Windspeed Class, MPH								
	>5	>10	>15	>20	>25	>30	>35	>40	>45
ENE	24 (18)	24 (18)	23 (23)	13 (22)	3 (29)	2 (35)	1 (39)	1 (42)	-
E	24 (9)	23 (12)	18 (27)	14 (26)	10 (37)	9 (39)	7 (40)	2 (43)	1 (47)
ESE	12 (19)	12 (19)	12 (25)	12 (25)	4 (26)	1 (34)	1 (37)	-	-
SE	13 (12)	7 (14)	7 (17)	2 (24)	2 (28)	1 (39)	1 (39)	-	-
SSE	14 (16)	14 (16)	6 (18)	3 (23)	1 (26)	-	-	-	-
S	13 (11)	12 (13)	7 (19)	6 (24)	5 (32)	2 (31)	1 (38)	-	-
SSW	17 (16)	16 (17)	10 (21)	5 (26)	3 (27)	2 (35)	1 (38)	-	-
SW	21 (14)	21 (14)	15 (26)	15 (26)	4 (27)	1 (33)	-	-	-
WSW	17 (11)	14 (21)	14 (21)	9 (24)	5 (26)	3 (34)	1 (40)	1 (43)	-
W	24 (16)	24 (17)	14 (23)	12 (26)	6 (26)	3 (33)	1 (36)	-	-
WNW	22 (15)	22 (19)	16 (20)	7 (24)	3 (30)	2 (35)	1 (36)	-	-
NW	24 (17)	24 (17)	14 (19)	8 (28)	8 (28)	2 (32)	-	-	-

NOTE: Based on 13 years of hourly observation, 1949-1974

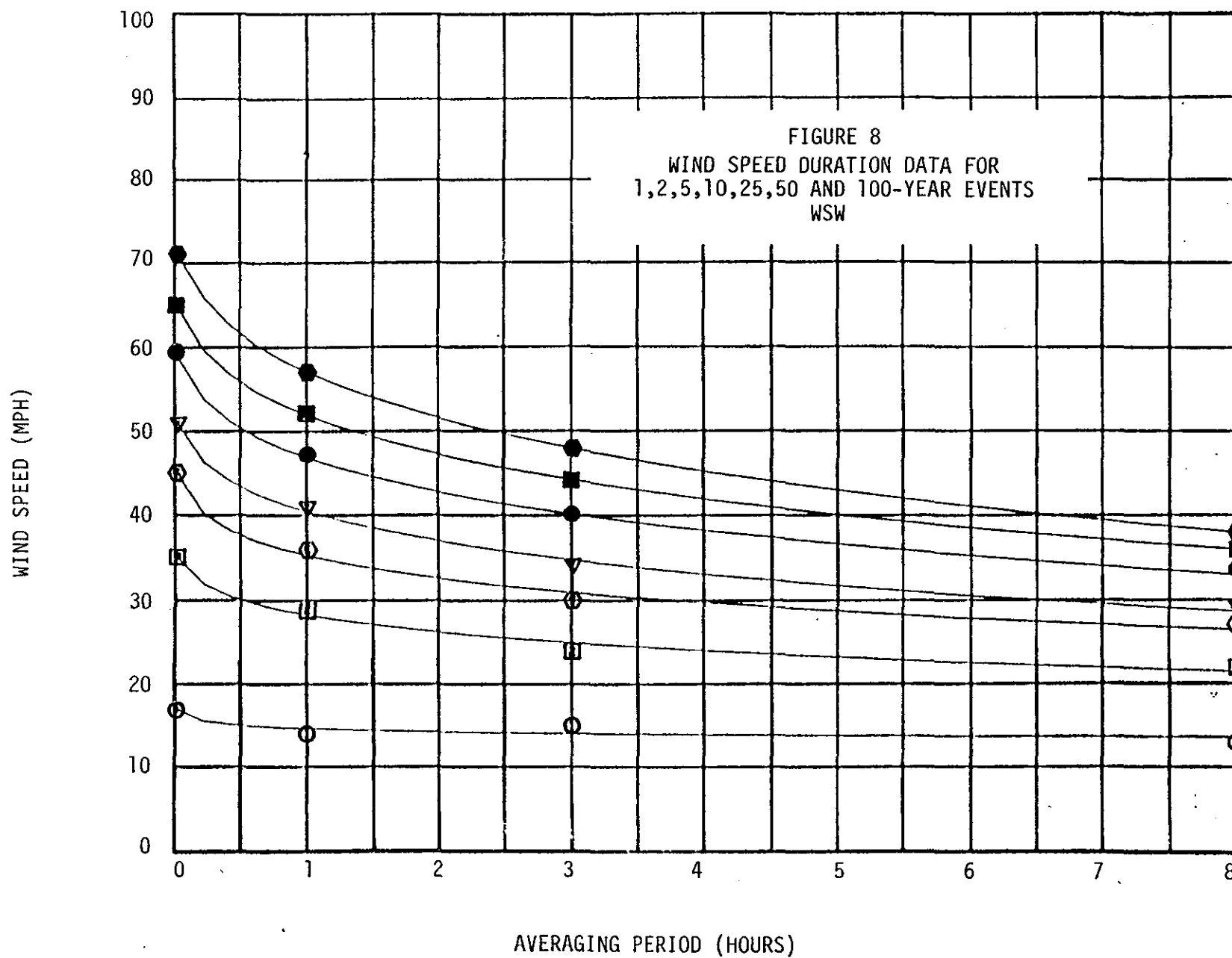


TABLE 10

BRIDGEPORT, CONNECTICUT
NATIONAL WEATHER SERVICE
MAXIMUM ONE-MINUTE AVERAGE WIND OBSERVATIONS
DAYS OF MAXIMUM TIDAL FLOODS
(1947-1975)

<u>Date</u>	<u>Maximum Speed</u> (mph)	<u>Direction</u>
21 Sep 1938 (Hurricane)	*	*
31 Aug 1954 (Hurricane-Carol)	41.7	NNE
14 Sep 1944 (Hurricane)	*	*
25 Nov 1950	64.5	E
6 Feb 1978	*	*
7 Nov 1953	35.4	SSE & NE
12 Sep 1960 (Hurricane-Donna)	41.7	NE
25 Oct 1980	*	*
14 Oct 1955	48.1	NE & ENE
19 Feb 1960	*	*
29 Mar 1984	*	*
12 Nov 1968	41.7	ENE
27 Sep 1985 (Hurricane-Gloria)	*	*
13 Apr 1961	55.7	E
6 Mar 1962	41.7	ENE
25 Dec 1978	*	*
30 Nov 1944	*	*
4 Apr 1973	41.7	E
9 Jan 1978	*	*
16 Feb 1958	41.7	E
20 Mar 1958	*	*
21 Sep 1961	*	*
10 Nov 1962	*	*
26 Dec 1969	35.7	ENE
19 Feb 1972	40.5	NE
2 Dec 1974	32.9	ENE
14 Oct 1977	*	*
31 Oct 1947	39.2	NNE
12 Mar 1959	36.7	E
14 Feb 1960	*	*
9 Mar 1961	*	*
16 Sep 1971	12.7	NNE

*Wind Data Not Available

(Events are listed in order of decreasing stillwater tidal level to conform with Table 12)

In southern New England, during Hurricane Carol (31 August 1954) gusts of 125 and 135 mph were experienced at Blue Hill, Massachusetts, and Block Island, respectively. Sustained 1-minute velocities ranging from 38 to 98 mph were registered.

Recorded wind velocities at a number of locations in southern New England and New York City, for the three great hurricanes of 1938, 1944, and 1954, are given in Table 11. More recent hurricanes, "Donna" (12 September 1960) and "Gloria" (27 September 1985), did not pack as much punch as the great hurricanes.

The wind data in Table 11 are for historical hurricanes that passed to the east of Stratford and caused high surges to enter the east entrance of Long Island Sound. The winds at Stratford in these three hurricanes were, in general, from the northern sector. This tended to decrease wave action in the study area. Hurricanes passing to the west of the area by a distance of 50 miles or so would produce critical winds from the southern sector. These winds would cause greater wave action.

c. Effects of Storms On Water Levels

Three distinct processes may produce an increased water level near the coast during storms.

(1) The Inverted Barometer Effect

In the deep sea, a reduction in atmospheric pressure is accompanied by a rise in the sea surface which will lead toward a constant pressure level at some distance below the water surface. Although for equilibrium to be achieved the water would have to rise about 13.25 inches for a pressure drop of one inch of mercury, the approximation of a one-foot rise in water level for one-inch fall in atmospheric pressure is often used. Nearshore boundary conditions at the bottom or sides may alter the response of the sea to pressure changes so that the actual rise is generally less than that indicated above, but it can be greater. This tendency for the water level to rise under low atmospheric pressure is often called the "inverted barometer effect."

(2) Wind Setup

Friction between the wind and the water surface generates a current, which is initially parallel with the wind, but which, because of the rotation of the earth, rotates toward the right with increasing time and increasing depth so that the water transport due to a steady wind on very deep water is about 90° to the right of the wind. In shallow water, far from the shore, the direction of the current differs little from the direction of the wind. Near the shore the current is constrained to flow parallel to the shore but, because of the earth's rotation, the mean free

TABLE 11

WIND VELOCITIESNew England Hurricanes of 1938, 1944, and 1954Velocity in Miles Per Hour

<u>Location</u>	<u>Sustained 5-Min.</u>	<u>Sustained 1-Min.</u>	<u>Maximum Gusts</u>	<u>Direction</u>
<u>Hurricane of 21 September 1938</u>				
New York, N.Y.	70	-	80	NW
New Haven, Conn.	38	-	46	NE
Hartford, Conn.	46	-	59	NE
Block Island, R.I.	82	-	91	SE
Providence, R.I.	87	95	125*	SW
Milton, Mass. (Blue Hill Observatory)	121	-	186	S
<u>Hurricane of 14 September 1944</u>				
New York, N.Y.	81	99	-	N
New Haven, Conn.	33	38	65	N & NE
Hartford, Conn.	50	62	109**	N
Point Judith, R.I.	85*	90*	-	SSE
Block Island, R.I.	82	88	100	SE
Providence, R.I.	43	49	90	SE
Milton, Mass. (Blue Hill Observatory)	67	77	-	-
<u>Hurricane of 31 August 1954</u>				
New York, N.Y.	-	-	61	NW
Bridgeport, Conn.	-	-	60	-
Hartford, Conn.	-	56	64	NE
New Haven, Conn.	-	38	65	N
Block Island, R.I.	-	98	135	SE
Providence, R.I.	-	90	105	ESE
Milton, Mass. (Blue Hill Observatory)	-	93	125	SE

* Estimated

** Taken from indicator; clocked for 4 seconds

surface slopes upward to the right of the wind. Thus both the component of the wind that is directed on shore and the component that is parallel to the shore, with the shore to the right, tends to produce above normal water level. The direct effect wind setup, is inversely proportional to the water depth. Thus the effect of a given wind velocity is greater at low tide than at high tide and is limited to shallow waters near the shore. The wind effect is approximately proportional to the square of the wind speed.

(3) Wave Setup

The mean water velocity due to periodic waves vanishes beneath the wave trough. Between the wave trough and the wave crest, however, there is always a net flow in the direction of wave propagation. The magnitude of this flow is proportional to the square of the wave height. Thus the mean current due to the waves increases more or less continuously from deep water to the breaker zone, thus producing a downward slope of the mean water surface from the region in which the bottom begins to affect the waves to the breaker zone. The wave amplitude must vanish in the region between the breakers and the water line, producing an upward slope of the water surface called the wave setup. The wave setup is often steeper than the wind setup, but it is restricted to a much more narrow region near the shore.

The wave setup is usually correlated with the wind setup because high wind and high waves are often correlated. However the process of wave generation extends much further seaward than the effective wind setup. Waves can travel as well far from their region of generation. Thus wave setup can occur in the absence of wind or even with an adverse wind.

The combined affects of winds, atmospheric pressure and wave setup are often called the storm surge. The contribution due to wave setup is often neglected.

3. COMBINED EFFECTS OF ASTRONOMICAL TIDES AND STORM SURGE ON WATER LEVEL

a. General. The total effect of astronomical tide combined with storm surge produced by wind, wave, and atmospheric pressure contributions is reflected in actual tide gage measurements. Since the astronomical tide is so variable at the study area, the time of occurrence of the storm surge greatly affects the magnitude of the resulting tidal flood level. Obviously, a storm surge of three feet occurring at a low astronomic tide would not produce as high a water level as would be produced if it occurred at a higher tide. It is important to note that the storm surge itself varies with time thus introducing another variable into the makeup of the total flood tide.

b. A Case Study

A sample water level record for Stratford showing the combined effects of astronomical tides and storm surge is depicted in Plate 1. A plot of the hourly observed tide heights for several hurricanes is presented. Also shown is the predicted astronomical tide. The storm surge, defined as the difference between the observed and the astronomical tides can be determined from this plate.

The peak storm surge of 21 September 1938 occurred near 7:30 pm at a predicted tide of about +2 feet above mean sea level. The maximum water level would have been nearly two feet higher if the surge peak had occurred about two hours later near the high astronomical tide. This demonstrates the importance of the timing of maximum surge and astronomical tide in providing maximum flood levels.

c. Summary of Extreme High Tides at Bridgeport.

A listing of maximum observed stillwater tide heights (measurements taken in protected areas in which waves are dampened out) has been developed for Bridgeport Harbor; (a location near the center of the study reach where such data are available); see Table 12. Also shown are the tide heights with an adjustment applied to account for the effect of rising sea level (see section 7). This listing was developed utilizing, (a) high watermark (COE), staff gage (Bridgeport Harbormaster) and recording tide gage (COE and National Ocean Survey, NOS) data gathered at Bridgeport (b) NOS recording tide gage data from New London stage related to Bridgeport and (c) historical account at Stamford stage related to Bridgeport. Data in Table 12 shows that several hurricanes or tropical storms have caused major tidal flood levels at Bridgeport. Therefore, it appears that although the extratropical storm is the prevalent type of storm affecting the study area, the tropical storm poses the greatest threat of extremely severe tidal flooding. Note that the recent hurricane "Gloria" of 27 September 1985 produced a modest increase above normal high tides at Bridgeport, this being related to passage of the weakened storm during lower predicted tide levels.

d. Tidal Flood Frequency.

A tide stage-frequency relationship for Bridgeport was previously developed utilizing a composite of (1) a Pearson type III distribution function, with expected probability adjustment, for analysis of historic and systematically observed annual maximum stillwater tide levels and, (2) a graphical solution of Weibull plot positions for partial duration series data. The resulting tide stage-frequency curve is shown on figure 9.

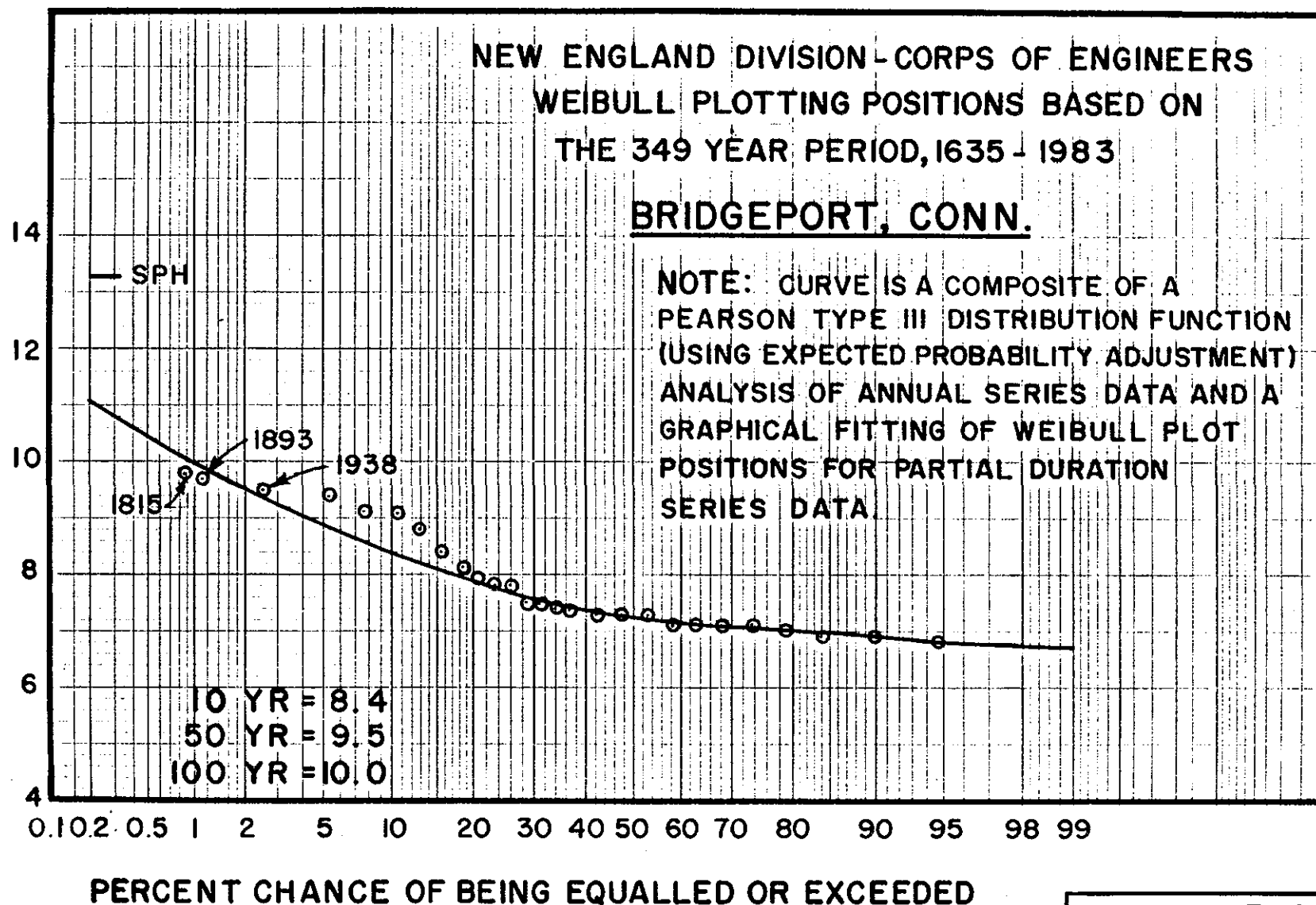
TABLE 12
New England Division
Corps of Engineers
BRIDGEPORT, CONNECTICUT

MAXIMUM TIDE LEVELS
(1938-1986)

Date	Observed Stillwater Elevation ----- (ft, NGVD)	Adjusted Elevation* (ft, NGVD)
21 SEP 1938(Hurricane)	9.2	9.5
31 AUG 1954(Hurricane-Carol)	9.2	9.4
14 SEP 1944(Hurricane)	8.8	9.1
25 NOV 1950	8.8	9.1
6 FEB 1978	8.7	8.7
7 NOV 1953	8.6	8.8
12 SEP 1960(Hurricane-Donna)	8.2	8.4
25 OCT 1980	8.2	8.2
14 OCT 1955	7.9	8.1
19 FEB 1960	7.9	8.1
29 MAR 1984	7.9	7.8
12 NOV 1968	7.8	7.9
27 SEP 1985(Hurricane-Gloria)	7.8	7.7
13 APR 1961	7.7	7.8
6 MAR 1962	7.7	7.8
25 DEC 1978	7.6	7.6
30 NOV 1944	7.4	7.7
4 APR 1973	7.4	7.4
9 JAN 1978	7.4	7.4
16 FEB 1958	7.3	7.5
20 MAR 1958	7.3	7.5
21 SEP 1961	7.3	7.4
10 NOV 1962	7.3	7.4
26 DEC 1969	7.3	7.4
19 FEB 1972	7.3	7.3
2 DEC 1974	7.3	7.3
14 OCT 1977	7.3	7.3
31 OCT 1947	7.2	7.5
12 MAR 1959	7.2	7.4
14 FEB 1960	7.2	7.4
9 MAR 1961	7.1	7.2
16 SEP 1971	7.1	7.1
22 DEC 1972	7.1	7.1
9 DEC 1973	7.1	7.1
8 NOV 1977	7.1	7.1
29 DEC 1966	7.0	7.1
22 MAR 1980	7.0	7.0
2 JAN 1987	7.0	6.9
20 NOV 1972	6.9	6.9
10 JAN 1977	6.9	6.8
27 NOV 1940	6.8	7.1
29 NOV 1945	6.8	7.1
8 DEC 1950	6.8	7.1
4 FEB 1961	6.8	6.9
23 OCT 1961	6.8	6.9
OCT 1972	6.8	6.8
28 FEB 1958	6.7	6.9
21 APR 1940	6.6	6.9
4 MAY 1954	6.6	6.8
29 DEC 1959	6.6	6.8
23 SEP 1815(Hurricane)	---	9.8
24 AUG 1893(Hurricane)	9.0	9.7

*Observed values after adjustment for rising sea level; adjustment made to 1975 sea level conditions based on NOS publication "Trends and Variability of Yearly Mean Sea Level, 1893-1972".

STILLWATER ELEVATION (FT, N.G.V.D.)



FREQUENCY OF
TIDAL FLOODING AT
BRIDGEPORT
HARBOR

CJW

1/87

e. Tidal Flood Profiles

NOS tide gage records and high watermark data gathered after major storms have been utilized in the development of profiles of tidal floods along the New England coast. Additionally, profiles of storm tides for selected recurrence intervals have been developed utilizing tide stage-frequency curves and high watermark information. A location map and profile for the reach of the New England coast under consideration is shown on Plates 2 and 3, respectively. Average stage-frequency information for each study community is summarized in Table 13. It should be noted that the mean tidal data shown on Plate 3 is from the tidal epoch that ended in 1941. This plate will be revised when NOS data for the 1960-78 epoch is finalized.

These represent the stillwater level of the open waters along the north shore of Long Island Sound and do not include the effects of wave action or coastal topographic configurations such as embayments, harbors, estuaries, breakwaters, barrier beaches or the like which can cause departures from the profile levels.

TABLE 13
TIDAL FLOODING WEST CENTRAL CONNECTICUT

Location	1-Yr	10-Yr	Average Stillwater Flood Elevation - FT, NGVD					SPH	1938	1954
			20-Yr	50-Yr	100-Yr	500-Yr				
Westport, CT	7.3	9.0	9.6	10.3	11.0	12.1	13.6	10.5	9.9	
Fairfield, CT	7.0	8.8	9.4	10.1	10.8	12.2	13.4	10.2	9.4	
Bridgeport, CT	6.8	8.5	9.0	9.7	10.4	11.8	13.3	9.6	9.3	
Stratford, CT	6.7	8.4	8.8	9.5	10.1	11.3	13.3	9.3	9.3	
Milford, CT	6.7	8.4	8.9	9.7	10.5	12.0	13.8	9.4	9.4	
W. Haven, CT	6.7	8.4	9.0	9.7	10.6	12.3	14.7	9.6	9.6	
N. Haven, CT	6.4	8.5	9.1	9.8	10.5	11.8	15.3	9.5	9.5	
E. Haven, CT	6.3	8.3	8.9	9.7	10.6	12.2	15.5	9.5	9.5	

4. NOTABLE STORMS

a. Introduction

The shores of Connecticut are vulnerable to the erosive action and flooding of wind-driven seas associated with major storms. When examining the effects of storms on the Connecticut coastline, one immediately recognizes that hurricanes are responsible for the most severe coastal flooding along the entire coast. In fact, 7 hurricanes have affected Connecticut since 1899. The orientation of the coastline determines the relative magnitude of the impact. The principal causes of severe flooding are the tropical storms (hurricanes) that push up ocean levels against the exposed southwesterly to southeasterly facing land mass. However,

southeasterly facing coastline is vulnerable to the storm waves generated by extratropical storms moving along the coast. Storm tide-surges resulting from wind and wave setup and barometric effects can be especially disastrous when coincident with high spring tides. Huge and furious waves, sometimes reaching heights of 20 feet or more, break on the offshore bars. Beach sand is cut away and transported by the turbulent surf to other locations along the shore or to deeper water. Cliff walls are undermined and slough into the rough seas. The height of the beach can be reduced by as much as 10 feet in a single spot when a high tide brings the storm surf on to the beach (Giese and Giese, 1974).

b. Historical Hurricanes

The earliest hurricanes recorded in New England are known to have affected the coastal areas of Massachusetts and Rhode Island. Since there was very little development along the Connecticut shore until after 1638, there are no available records to indicate that these early storms affected Long Island Sound. It is reasonable to assume that they caused inundation of the coastal lowlands as hurricane of recent years that have caused tidal flooding along the coasts of southern Massachusetts and Rhode Island also caused flooding along the Connecticut coast. The two earliest hurricanes of record in New England, 15 August 1635 and 3 August 1638, created flood levels apparently higher than the recent floods of 1938 and 1954, and were probably the greatest experienced in New England during the past 300 years.

These early hurricanes were not accompanied by significant loss of life or property damage due to the small degree of development along the coastline of the Sound. However, the recurrence of the two earliest hurricanes under present conditions would cause extensive damages, possibly in excess of the damages sustained in September 1938.

Early newspaper and journal accounts contain a number of references to intense storms accompanied by destructive winds during the 18th and 19th centuries, the more notable of which are chronologically listed as follows:

30 October 1723	3 September 1821
24 October 1761	8 September 1869
23 September 1815	24 August 1893

c. Recent Hurricanes and Severe Coastal Storms

(1) General. In the last 50 years the southern coast of New England has been subjected to tidal flooding from three major hurricanes, severe flooding from the hurricanes of September 1938 and August 1954 and moderate flooding from the hurricane of September 1944. Hurricanes "Donna" (12 Sep 1960) and "Gloria" (27 Sep 1985) produced relatively minor

flooding in Connecticut. The tracks of these and other selected hurricanes are shown on Figure 4. The hurricanes of 16 September 1903 and 22 June 1972 (Agnes) also affected Connecticut to some degree according to the National Weather Service. "Diane", shown on Figure 4, had been downgraded to a tropical storm when it passed New England. It was included on the figure because it produced record riverine flooding in many areas. The two most severe coastal storms based on adjustment of flood levels to 1975 sea level conditions occurred in November 1950 and November 1953. Table 14 presents data on the maximum tide elevation, coincident predicted tide and surge at time of maximum tide at Bridgeport for the two greatest hurricanes and the two most severe storms. Table 12 lists the maximum stillwater tide elevations which have occurred from 1938 to date at Bridgeport. Tidal flood level profiles for the two greatest hurricanes of recent years in Long Island Sound are shown on plates 2 and 3.

(2) Hurricanes

(a) September 21, 1938. Damage caused by tidal flooding from this hurricane was the greatest ever experienced in Long Island Sound. The center of the hurricane entered Connecticut perpendicular to the coast about 15 miles east of New Haven on 21 September and then proceeded northwesterly at a forward speed of 50 to 60 mph. The peak of the hurricane tide arrived about one to two hours before the predicted normal high tide throughout most of the Sound, causing the extreme tide levels. As can be seen on Table 14 the tidal surge at Bridgeport was about seven feet higher than the predicted tide.

The maximum recorded wind velocity in New England was a gust of 186 mph at the Blue Hills Observatory, Milton, Massachusetts, where a sustained five-minute wind of 121 mph was also recorded. At other locations along the southern coast, sustained five-minute velocities ranging from 38 to 82 mph were experienced. The lowest pressure recorded in the area during the storm was 28.04 inches at Hartford, Connecticut. A plot of the estimated tide levels at Stratford is shown on Plate 1.

TABLE 14
TIDAL DATA
SEVERE STORMS

<u>Event</u>	<u>Bridgeport Conn.</u>
<u>Hurricane, 21 Sept. 1938</u>	
Maximum El. (ft, ngvd)	9.2
Predicted Tide (ft, ngvd)	2.5
Surge (ft)	6.7
<u>Hurricane, 31 Aug. 1954</u>	
Maximum El. (ft, ngvd)	9.2
Predicted Tide (ft, ngvd)	4.1
Surge (ft)	5.1
<u>Storm, 25 Nov. 1950 (first high tide)</u>	
Maximum El. (ft, ngvd)	8.8
Predicted Tide (ft, ngvd)	3.7
Surge (ft)	5.1
<u>Storm, 25 Nov. 1950 (second high tide)</u>	
Maximum El. (ft, ngvd)	8.8
Predicted Tide (ft, ngvd)	2.5
Surge (ft)	6.3
<u>Storm, 7 Nov. 1953</u>	
Maximum El. (ft, ngvd)	8.6
Predicted Tide (ft, ngvd)	3.9
Surge (ft)	4.7

(b) September 14, 1944. In this hurricane, the eye of the storm passed inland just west of Pt. Judith, Rhode Island and continued in a northeasterly direction at a forward speed of 30 to 35 mph veering out to sea at Boston, Mass. The hurricane tide arrived in the Sound at about mean tide at the eastern end and about two hours after predicted high tide at the western end, which resulted in moderately high ocean levels. (See Plate 1).

The maximum gust was an estimated 104 mph at Hartford, Connecticut. A one-minute wind of 99 mph and a five-minute velocity of 81 mph were recorded at New York City. The lowest pressure of 28.30 inches was recorded at Westerly, Rhode Island.

(c) August 31, 1954 (Carol). The second most severe hurricane to strike southern New England in over 300 years occurred just 16 years after the record 1938 event. The center of this storm crossed the shoreline of

Connecticut near New London with a forward speed of about 45 mph and then followed a general northerly path across New England. As the hurricane surge occurred at or near predicted normal high tide within the Sound, tide levels rose to near record heights. Tidal surges ranged from five to eight feet higher than predicted tides.

The wind attained a maximum gust of 135 mph and a five minute sustained velocity of 98 mph at Block Island, Rhode Island. Minimum pressures of 28.2 and 28.3 inches were recorded at Storrs and New London, Connecticut, respectively. A plot of the hurricane tide levels at Stratford is presented in plate 1.

(d) September 27, 1985 (Gloria) Hurricane Gloria made landfall in Westport, after crossing Long Island, at 1215 EST. The "eye", or center of the hurricane, then continued on its north-northeastward track, passing near Hartford before exiting the state at Suffield at about 1315 EST. Wind gusts of hurricane force ripped through the southern and central, as well as the eastern portion of the state, with the peak gust for the entire state recorded to 92 MPH at Bridgeport. The lowest sea level pressure was 28.50 inches recorded at Bridgeport, while the lowest pressure at Hartford was 28.69 inches, corrected for sea level. Other peak wind gusts included 82 MPH at Hartford, 75 MPH at New Haven, and 66 MPH at Windsor Locks. Along the coast, up to 20,000 people were evacuated from their homes from Greenwich to Stonington and hundreds of small craft were torn from their moorings and damaged or sunk. However, the coastal flooding was at a minimum despite tides of 2 to 4 feet above normal, since Gloria reached the coast near low tide. At Old Saybrook, 5,000 persons were evacuated from their homes and a number of houses right along the coast were damaged by waves along the beach. Five docks were ripped up in Milford Harbor and about one hundred pleasure craft were torn from their moorings. In western and northwestern Connecticut, rain in amounts of 2 to 5 inches fell during Gloria, resulting in some minor flooding.

(3) Extratropical Storms.

(a) November 25-26, 1950. The storm of 25 November 1950 started as a disturbance from Virginia, intensified rapidly and moved north-northeastward reaching New England on the 25th, resulting in the most violent storm of its kind on record. Tidal flooding was experienced along the entire Connecticut coast and was particularly severe west of New Haven. The two crests of severe tidal flooding, approximately equal in height, occurred on two successive tide cycles. At New Haven, the recorded maximum one-minute sustained wind velocity and gust were 55 and 77 miles per hour, while corresponding velocities at Hartford were 70 and 100 mph. The wind shifted slowly from east to southeast, then south, thus becoming directly onshore at all locations along the Connecticut coast during the storm. The strong gale wind velocities were of longer duration than in the 1938 and 1944 hurricanes. Although the lower limit of

hurricane wind velocity was exceeded, it was not classified as a hurricane since it was not of tropical origin.

(b) November 6-7, 1953. The storm of 6 to 7 November 1953 commenced during the early morning of the 6th when a low pressure area off the Georgia coast moved rapidly up the Atlantic seaboard, developed into a major storm and brought rain, snow and high winds to northeastern United States. It reached southern New England the night of the 6th, moving northerly over the rest of the section of the following day. The crest of severest tidal flooding occurred on the 7th coincident with the first predicted high tide for the day at most locations on the Sound. Maximum wind gusts at Block Island, Rhode Island were 98 miles per hour. Although the entire New England coast was affected to some degree by this storm, damage was heaviest along the Connecticut shore of Long Island Sound.

(c) February 6, 1978. A storm characterized as "the blizzard of 1978" developed off the Carolina coast on 6 February and moved slowly northward along the Atlantic seaboard where it stalled for nearly 12 hours between Long Island and Cape Cod before redeveloping further eastward on the 7th. Accompanying winds gusted to over 50 miles per hour in New York and Connecticut, with gusts to 79 and 92 mph at Boston and Chatham, Massachusetts, respectively. Maximum wind gusts at the Stamford Hurricane Barrier were 45 miles per hour from the north-northeast and the minimum barometer reading was 29.28 inches. About two feet of snow covered the state as this "granddaddy" northeast coastal storm gusted through the area. Tides 3 to 4 feet above normal caused extensive coastal flooding and wave battery. Hundreds of people were evacuated from Norwalk.

In Old Saybrook, several marinas were seriously damaged. In the eastern portions of the state this blizzard is being called the greatest of the century.

5. FLOODING IN TIDAL ESTUARIES

There are numerous streams and rivers along the West Central Connecticut coastlines that empty into Long Island Sound. The greatest floodflows on these waterways have been associated with intense rainfall. The flood runoff from the many streams and smaller rivers have no significant effect on the floodwater levels within their respective tidal estuaries. The maximum water levels in these estuaries occurred during major hurricanes and resulted from the high tidal surges.

The estuaries of the three largest rivers extended a considerable distance inland and pertinent information is shown as follows:

<u>River</u>	Drainage Area (sq. mi.)	<u>Estuary Limits</u>	
		Approximate Length (miles)	Head of Tidewater
Housatonic	1,949	12	Derby, Conn.
Quinnipiac	166	10	North Haven, Conn.
Saugatuck	92	3	Westport, Conn.

The highest water levels in the Saugatuck and Quinnipiac estuaries and lower parts of the Housatonic estuary are associated with both tidal and river flooding.

6. STANDARD PROJECT HURRICANE

Based on the history and analysis of hurricanes in the Narragansett Bay and Long Island Sound areas, the Standard Project Hurricane (SPH) for the design of hurricane protective structures of Southern New England was developed. This SPH is representative of the most severe combination of meteorological conditions that are considered reasonably characteristic of the region. The design storm has been established through the cooperation of the National Weather Service and the Beach Erosion Board, assisted by the Research Foundation of the Agricultural and Mechanical College of Texas. It was based on the transposed Cape Hatteras hurricane of September 1944, which is the largest according to SPH indices by the National Weather Service. The SPH criteria were established by enveloping observed hurricane parameters such as central pressure and radius of maximum winds separately and smoothing geographically. In deriving the SPH, the 1944 storm was transposed so that it would be entirely over water between Cape Hatteras and the New England coast, resulting in a Central Pressure Index (CPI) of about 27.8 inches near the mouth of Narragansett Bay, Buzzards Bay and Long Island Sound. This CPI was approximately 0.5 inch lower barometric pressure than actually occurred in September 1944. The center of the transposed hurricane was moved northerly with forward speeds of 30 to 40 knots along a track passing about 50 nautical miles west of Montauk Point, Long Island, New York. The track of this storm is shown on plate 4.

In general, the faster moving storms (30 knots and greater) produce higher wind velocities in Narragansett Bay, Buzzards Bay and Long Island Sound. Although 50- or 60-knot storms can produce the highest wind velocities, the storm travels so rapidly that it tends to run ahead of the tidal surge. This tendency would have less effect on surge build-up than with the 40-knot storm which has a larger radii of maximum winds and therefore was selected as a basis for critical conditions and calculation of surge heights at all communities within the Sound. Calculations showed that the 40-knot storm, with large radii of maximum winds, would cause the

greatest surge at Narragansett Bay, Buzzards Bay and the eastern and western portions of Long Island Sound. The 30-knot storm, with large radii of maximum winds produced higher surge heights for the central portion of Long Island Sound. A velocity of one knot is equivalent to 1.15 miles per hour.

The SPH stillwater elevation can be determined by adding the design surge to a mean spring high water elevation. In the study area, the mean spring tide elevation is predicted to occur on an average of 16 times a month during the hurricane season. Pertinent data on the SPH are summarized in Table 15. The maximum SPH flood level throughout the study area is shown on plates 2 and 3.

Table 15

STANDARD PROJECT HURRICANE
TIDAL DATA AT SELECTED LOCATIONS IN
LONG ISLAND SOUND

<u>Location</u>	<u>Miles from Willets Point</u>	<u>SPH Speed in Knots</u>	<u>Surge In Feet</u>	<u>Mean Spring High Water In Ft. NGVD*</u>	<u>Maximum Tidal El. In Ft. NGVD</u>
Bridgeport, CT	41.8	30	9.0	4.2	13.2
New Haven, CT	54.2	30	11.2	4.1	15.3

* NOTE: Based on data available prior to 1968.

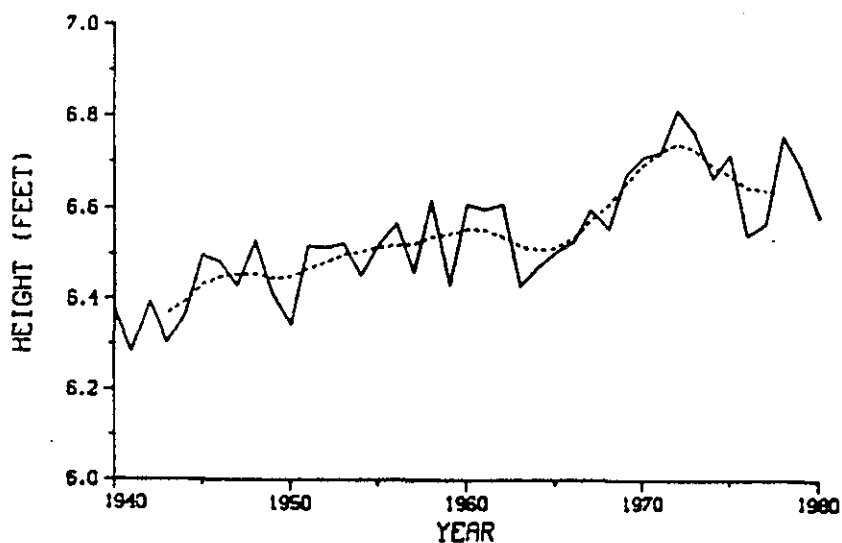
7. RISING SEA LEVEL

a. Historic Rise

Sea level has been rising world wide at varying rates for thousands of years. Since the maximum advance of the last glacier at about 13,000 B.C., sea level has risen approximately 430 feet (Meade 19__). With retreat of the glacial ice, the phenomenon of "rebound" of the landmass has accounted for more than 600 feet of increased elevation in northern areas of New England where the ice sheet was very thick. The mean height of the sea, with respect to the adjacent land, has been rising in the United States with the exception of Alaska and possibly very northern New England where rebound may still be occurring. The rate of rise on the east coast has generally been 1 to 1-1/2 feet per century. This apparent change in sea level has been ascribed to a combination of increased water volume in the ocean from melting glaciers and subsidence of the land in some regions. Figure 10 depicts the historic sea level rise from 1940-80 along the northern east coast (Hicks, 1983). At Bridgeport Harbor, the rise has been estimated to be slightly less than 0.1 foot per decade. Sea level determination is generally revised at intervals of about 25 years to

FIGURE 10

NORTHERN EAST COAST



Northern east coast area mean with damping array.

Northern East Coast

Trend	2.6 mm/yr	.009 ft/yr
Standard Error of Trend	$\pm .3$ mm/yr	$\pm .0011$ ft/yr
Variability ^C	± 24.5 mm	$\pm .080$ ft

Northern East Coast to Cape Hatteras

Portland, ME
 Seavey Island, ME (Portsmouth, NH)
 Boston, MA
 Newport, RI
 Willets Pt., NY
 New York (The Battery), NY
 Atlantic City, NJ
 Baltimore, MD
 Annapolis, MD
 Solomons Island, MD
 Washington, DC
 Hampton Roads (Norfolk), VA
 Portsmouth, VA

Sea Level Variations for the United States 1855-1980

Stacy D. Hicks

account for the changing sea level phenomenon. The National Ocean Survey is presently engaged in completing the process of reducing tide data from the 1960-1978 tidal datum epoch to make such a revision. Thus, the present local mean level of the sea at a given location along the coast can be expected to be several tenths of a foot higher than the National Geodetic Vertical Datum that was established as the mean sea level in 1929 and which remains fixed in time and space.

b. Future Sea Level Rise

In recent years there has been much discussion regarding a potential increased rate of future sea level rise. This phenomenon is related to a gradual warming of the earth's atmosphere associated with increased emissions of carbon dioxide and other gases on earth. The warmed atmosphere may increase the rate of melting of polar ice caps, thereby hastening the rate at which ocean levels appear to be rising. The scientific community appears in general agreement that the rate of sea level rise will increase; however, there is lack of precision and agreement as to how much the increase will be. EPA and others have made projections employing mathematics models which simulate the processes involved. These are summarized in Table 16. It can be seen that the increase in sea level by 2075 could be as little as about one foot or as much as seven feet. A middle estimate of 3 to 4 feet is accepted by many experts. This middle ground would yield an increase of nearly four fold over historic rates in New England. Should the predictions come true, a significant increased threat of flooding and erosion should be expected. Today's flood which occurs on average every 100 years could become an annual event.

c. Corps Policy Regarding Sea Level Rise

The Corps policy regarding sea level rise is one of concern rather than alarm. The Corps is trying to stay aware of ongoing developments to further define the complex issue keeping in mind the inherent uncertainty in any projections. A 21 March 1986 letter from the Office of the Chief of Engineers stated our policy as follows:

(1) Predicting future sea level rise is risky because there are so many variables and, as yet undefined interrelationships.

(2) Until substantial evidence indicates otherwise, we will maintain the procedure of considering only local regional history of sea level changes to project a rise or fall for a specific project.

(3) Where long periods of tidal records exist and are used in determining the exceedence frequency relationship for coastal flood levels, it may be necessary to adjust the water level records for relative sea level changes when such changes are significant.

TABLE 16
ESTIMATES OF FUTURE SEA LEVEL RISE (FEET)

<u>Investigator</u>	<u>Total Rise in Specific Years*</u>					
	<u>2000</u>	<u>2025</u>	<u>2050</u>	<u>2075</u>	<u>2085</u>	<u>2100</u>
<u>NAS (1983)</u>	-	-	-	2.3	-	-
<u>EPA (1983)</u>						
Low	0.2	0.4	0.8	1.2	-	1.8
Mid-Range Low	0.3	0.9	1.7	3.0	-	4.7
Mid-Range High	0.4	1.3	2.6	4.5	-	7.1
High	0.6	1.8	3.8	7.0	-	11.3
<u>Hoffman et al. (1986)</u>						
Low	0.1	0.3	0.7	1.2	1.4	1.9
High	0.2	0.7	1.8	6.3	8.5	12.1

* NOTE: Only EPA reports made year-by-year projections for the next century

SOURCE: "The Causes and Effects of Sea Level Rise,"
 James G. Titus, U.S. Environmental Protection Agency

(4) Prudence may require an allowance in a project design for the continuation over the project design life of an established significant long-term trend in relative sea level rise.

(5) Consideration must be given to the relative magnitude of the suggested allowance and the confidence band of the data the designer is using and the tolerance allowed in constructing the project.

(6) Consider whether it is more cost effective to include the allowance for significant sea level rise in the initial construction or to plan for modification later after the need for such is demonstrated.

Table 17 compares the frequency of tidal flooding in 2075 to that in 1975 assuming that the historic rate of rise of 0.1 feet per decade were to continue. Even under these conditions today's 100-year flood could become about a thirty year event.

As events continue to unfold and more precision is gained in estimating future sea level rise, additional policy guidance is sure to follow. In an effort to make informed policy judgments the Corps Coastal Engineering Research Center is conducting an annotated bibliography on sea level rise. As well, plans have been made to embark on a study to determine the impacts of sea level rise on coastal engineering. If funded, his effort will surely yield other valuable information with which to make informed decisions.

Table 17
FREQUENCY OF TIDAL FLOODING
BRIDGEPORT, CONNECTICUT

Average Return Period (years)	1975 Stillwater Elevation (feet, ngvd)	2075* Projected Stillwater Elevation (feet, ngvd)
10	8.4	9.4
50	9.5	10.5
100	10.0	11.0

*Based on projecting a historic rise in relative sea level of about 0.1' per decade.

8. CLIMATOLOGY

a. General

The southern coastal area of New England has a temperate and changeable climate marked by four distinct seasons. Owing to the moderating influence of Long Island Sound and the Atlantic Ocean, and particularly the variable movements of high and low pressure systems approaching from the west and southwest, extremes of either hot or cold weather are rarely of long duration. In the winter, coastal storms frequently bring rainfall to the shore areas and snow in the inland more northerly regions of Connecticut. The prevailing winds are northerly in the fall and winter, northwesterly in the spring and southerly in the summer. High winds, heavy rainfall and abnormally high tides occur with unpredictable frequency. Hurricanes occur most frequently during August, September and October.

b. Temperature

Since 1896, temperature records have been maintained at Bridgeport Municipal Airport located in adjacent Stratford. The mean annual temperature is approximately 51° Fahrenheit, with January and February the coldest months averaging 30° and July the warmest, 73°. Freezing temperatures are common from late November through March. Table 18 is a summary of the mean monthly and maximum and minimum temperatures recorded at the Bridgeport National Weather Service station. Temperatures are based on the 75-year period of record from 1896 through 1970.

c. Precipitation

The average annual precipitation over Stratford, about 44.6 inches, is rather evenly distributed throughout the year. Table 18 contains a summary of the average monthly precipitation amounts at the Bridgeport National Weather Service station for the 77-year period of record, 1894 through 1970, inclusive. Dense fog occurs about 14 days per year and averages about one day a month with a slightly greater frequency in December and January.

d. Snowfall

Snowfall in the Stratford area averages about 35 inches. Monthly and annual average snowfall for the Bridgeport station, based on the 72-year period from 1899 through 1970 are shown in Table 19.

e. Storm Rainfall

Rainfall amounts and tidal elevations for recent hurricanes and severe storms which have produced either heavy rainfall and/or excessive tidal heights are summarized in Table 20.

TABLE 18

MONTHLY TEMPERATURE AND PRECIPITATION
NATIONAL WEATHER SERVICE STATION -
BRIDGEPORT, CONNECTICUT

<u>Month</u>	Temperatures in Degrees F. 1896-1970, Inclusive 75 Years of Record			Precipitation in Inches 1894-1970, Inclusive 77 Years of Record		
	<u>Mean</u>	<u>Maximum</u>	<u>Minimum</u>	<u>Mean</u>	<u>Maximum</u>	<u>Minimum</u>
January	29.4	68	-14	3.57	7.88	0.51
February	29.8	70	-20 ⁽²⁾	3.42	6.32	0.85
March	37.7	85	1	4.05	9.64	0.28
April	48.0	97	9	3.82	9.41	0.69
May	57.1	95	26	3.70	10.18	0.49
June	67.5	99	34	3.19	8.48	0.06 ⁽⁵⁾
July	73.1	103 ⁽¹⁾	44	3.92	18.77 ⁽³⁾	0.45
August	71.4	101	38	4.25	13.29	0.20
September	65.2	98	32	3.61	14.15	0.09
October	54.7	90	20	3.45	10.72	0.30
November	43.7	80	8	3.80	7.60	0.81
December	32.4	67	-12	3.81	9.85	0.33
ANNUAL	50.8	103 ⁽¹⁾	-20 ⁽²⁾	44.59	64.23 ⁽⁴⁾	23.03 ⁽⁶⁾

(1) 22 July 1957 (2) 9 February 1934 (3) July 1897 (4) 1901 (5) June 1949 (6) 1964

TABLE 19

MEAN MONTHLY SNOWFALL AT
NATIONAL WEATHER SERVICE STATION
BRIDGEPORT, CONNECTICUT
(Average Depth in Inches)

1899-1970, Inclusive
72 Years of Record

<u>Month</u>	<u>Snowfall</u>
January	8.9
February	10.1
March	6.7
April	1.1
May	0.0
June	0.0
July	0.0
August	0.0
September	0.0
October	0.0
November	1.4
December	6.5
ANNUAL	34.7

TABLE 20

STORM RAINFALL AT NATIONAL WEATHER SERVICE STATION -
BRIDGEPORT, CONNECTICUT AND MAXIMUM TIDAL ELEVATIONS
AT STRATFORD, CONNECTICUT, LONG ISLAND SOUND

<u>Hurricane or Other Storm</u>	<u>Accumulated Rainfall in Inches</u>					<u>Maximum Tidal Elevation</u>	
	<u>3-Hour</u>	<u>6-Hour</u>	<u>12-Hour</u>	<u>24-Hour</u>	<u>Total</u>	<u>Height in Feet, msl</u>	<u>Day of Month</u>
13-14 July 1897	-	4.4	7.3	8.11	-	-	-
17-21 Sept. 1938	1.8*	2.3*	3.4*	5.08	11.16	9.2	21
12-15 Sept. 1944	3.8*	4.8*	5.0*	5.80	10.74	8.8	14
25-26 Nov. 1950	0.70	1.15	1.36	1.36	1.43	8.8	25
6-7 Nov. 1953	0.23	0.40	0.68	0.85	0.85	8.6	7
30-31 Aug. 1954	0.83	1.13	1.62	1.62	1.72	9.2	31
Carol							
10-11 Sept. 1954	1.54	2.30	3.11	3.50	3.50	5.6	11
Edna							
11-13 Aug. 1955	1.16	1.68	2.18	3.97	4.53	below 4.0	12
Connie							
18-19 Aug. 1955	1.00	1.61	1.82	2.57	2.89	5.3	19
Diane							
14-17 Oct. 1955	2.33	2.85	3.33	5.84	7.15	7.9	14
11-12 Sept. 1960	2.41	3.62	3.89	4.67	5.01	8.2	12
Donna							
19-21 July 1963	2.61	2.61	2.61	2.61	4.11	6.0	19
29-30 Nov. 1963	0.95	1.32	1.44	1.49	1.49	5.9	29

* Estimated

The storm of 13 July 1897 caused heavy rainfall throughout most of New England, producing four inches or more at most stations in Connecticut. There is no record of tidal flooding during this storm.

The hurricane of 21 September 1938 was preceded by a low pressure area which formed over the middle Missouri and Lake Superior region on the 16th, moved over Lake Michigan on the 18th and Labrador on the 20th causing heavy rainfall over most of New England. The rainfall occurred prior to the hurricane tidal surge at Stratford which reached its crest at 7:30 PM on the 21st. Precipitation amounts during the tidal surge were negligible.

Precipitation during the period 12-15 September 1944 was the result of a storm that preceded the hurricane and the rainfall that accompanied the hurricane. Rain starting on the 12th ended early on the morning of the 14th, some nine hours before the start of the hurricane rainfall. The hurricane passed inland between Charlestown and Point Judith, Rhode Island at approximately 2220, EST on 14 September.

The total 2-day rainfall during hurricane "Carol" (31 August 1954) in the Bridgeport-Stratford area was only 1.72 inches. Hurricane "Edna" only 10 days later brought heavier rainfall. From 2200 EST, 10 September to 1300 on 11 September 1954 the total rainfall was 3.50 inches. The tidal crest at Stratford occurred at 0945 on 11 September. The rainfall in this area associated with hurricane "Connie" (11 to 13 August 1955) amounted to 4.53 inches of which 3.97 occurred within a 24-hour period.

The total rainfall in the Bridgeport-Stratford area associated with hurricane "Diane" (18 to 19 August 1955) was 2.89 inches. The high tide elevation was well below damage level.

The storm of 14 to 16 October 1955 caused five successive high tides in the Bridgeport-Stratford area, all above seven feet ngvd. Rainfall was heavy with most of it occurring between 0200 on the 15th and 0200 on the 16th.

During hurricane "Donna" 11 to 12 September 1960, 4.67 inches of rain occurred in the 24-hour period coincident with the maximum tidal elevation

Precipitation data and tidal heights for the 1944 and 1954 hurricanes are shown on plate 1.

f. Rainfall Frequencies

Rainfall amounts for various frequencies and durations derived from data published in National Weather Service (U.S. Weather Bureau) Technical Paper 40, "Rainfall Frequency atlas of the United States," are shown in Table 21.

TABLE 21

RAINFALL FREQUENCY
PRECIPITATION IN INCHES
STRATFORD, CONNECTICUT

<u>Duration</u> <u>in Hours</u>	<u>Exceedence Interval in Years</u>			
	<u>10</u>	<u>25</u>	<u>50</u>	<u>100</u>
1	2.05	2.4	2.6	3.0
2	2.55	3.0	3.3	3.7
3	2.85	3.3	3.6	4.1
6	3.55	4.1	4.5	5.1
12	4.15	5.0	5.3	6.1
24	5.05	5.8	6.4	7.2

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10. GLOSSARY OF TERMS

Bar - An offshore ridge or mound of sand, gravel, or other unconsolidated material submerged, at least at high tide; especially at the mouth of a river or estuary, or lying a short distance from, and usually parallel to the beach.

Beach - The zone of unconsolidated material that extends landward from the low water line to the place where there is marked change in material or physiographic form ... or to the line of permanent vegetation (usually the effective limit of storm waves). The seaward limit of a beach - unless otherwise specified - is the mean low water line.

Beach Erosion - The carrying away of beach materials by wave action, tidal currents, littoral currents, or wind.

Berm - A nearly horizontal portion of the beach or backshore formed by the deposit of material by wave action. Some beaches have no berms, others have one or several.

Centigrade - A thermometer temperature scale in which 0 degrees marks the freezing point and 100 degrees the boiling point of water at 760 mm (of mercury) barometric pressure.

Currents - Ebb, flood and coastal currents are due to tidal phenomena. Other currents are derived from winds and differential atmospheric pressures.

Fahrenheit - A temperature scale in which 32 degrees marks the freezing point and 212 degrees the boiling point of water at a 760 mm barometric pressure.

Fetch - The continuous area of open water over which the wind blows in a constant direction. In enclosed bodies of water it would usually coincide with the longest axis in the general wind direction. The FETCH LENGTH, in wave forecasting, would be the horizontal distance (in the direction of the wind) over which the wind blows.

Gradient - The change in a variable quantity, as temperature or pressure, per unit distance.

Knot - A velocity equal to one nautical mile (6,080.2 feet) per hour (about 1.15 statute miles per hour).

Mean Sea Level Datum - Denotes the National Geodetic Vertical Datum (NGVD) established in 1929 as a permanent nationwide standard leveling reference datum net.

Neap Tide - A tide occurring near the first and third quarters of the moon, when opposing tidal forces cause the water level to rise and fall the least from the mean level.

Runup - The rush of water up the face of a structure on the breaking of a wave. The height of runup is measured from the still-water level.

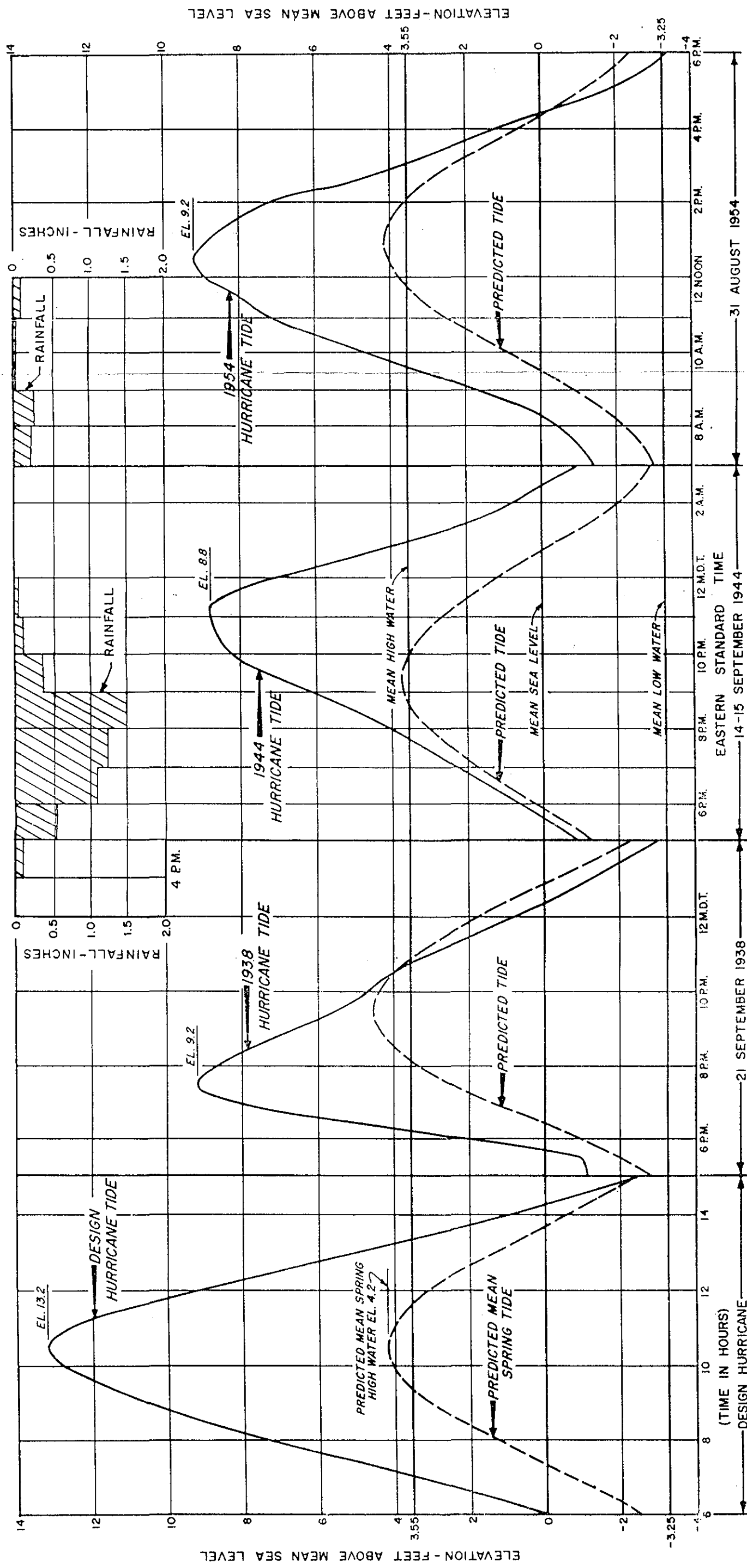
Spring Tide - A tide that occurs at or near the time of new and full moon and which rises highest and falls lowest from the mean level.

Still Water Level - The elevation of the water surface if all wave action were to cease.

Storm Surge - The mass of water causing an increase in elevation of the water surface above the predicted astronomical tide at the time of a storm; it includes wind set-up and barometric effects.

Tidal Range - The difference in height between consecutive high and low waters.

Wind Set-Up - The vertical rise in the stillwater level on the leeward side of a body of water caused by wind stresses on the surface of the water.

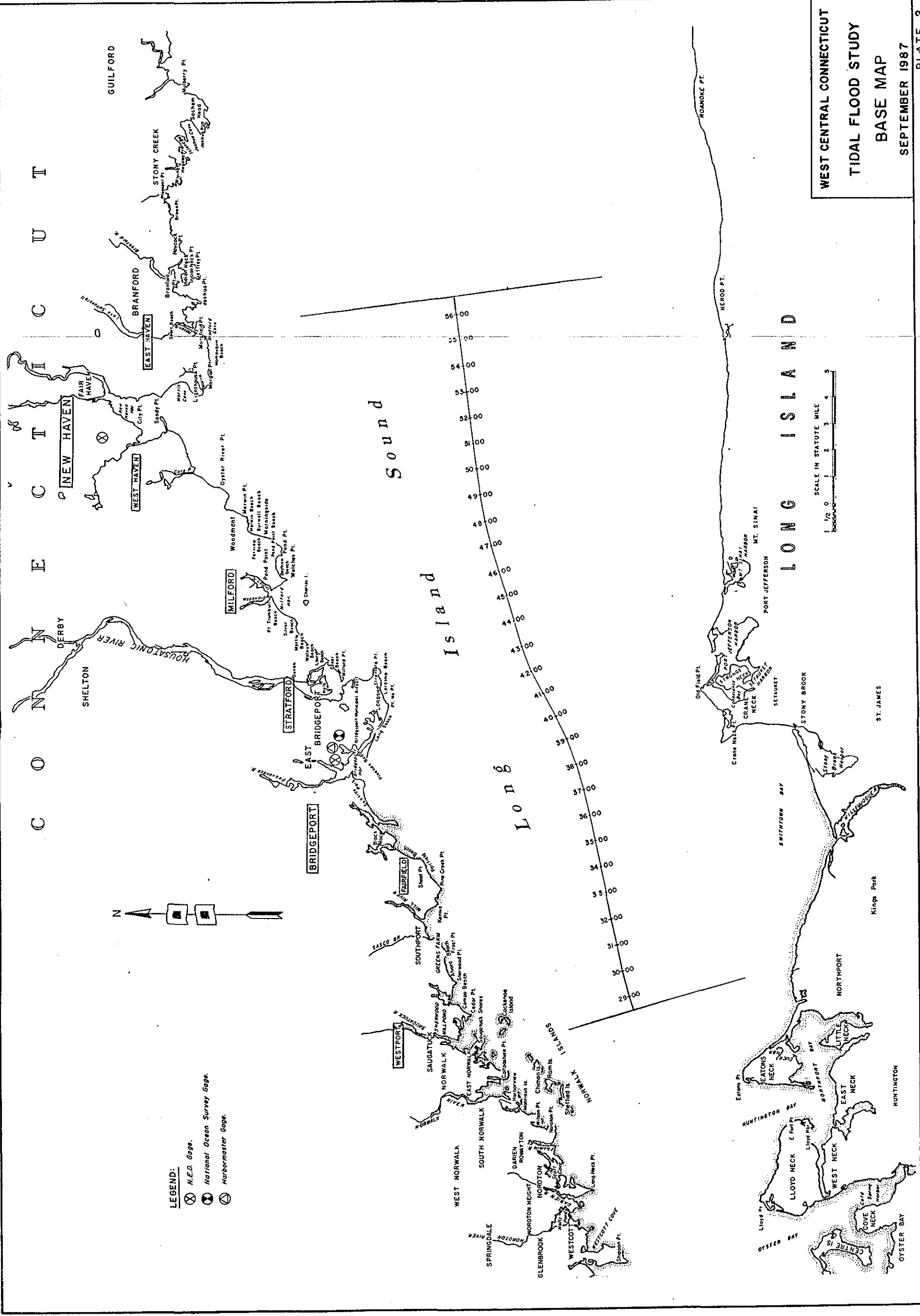


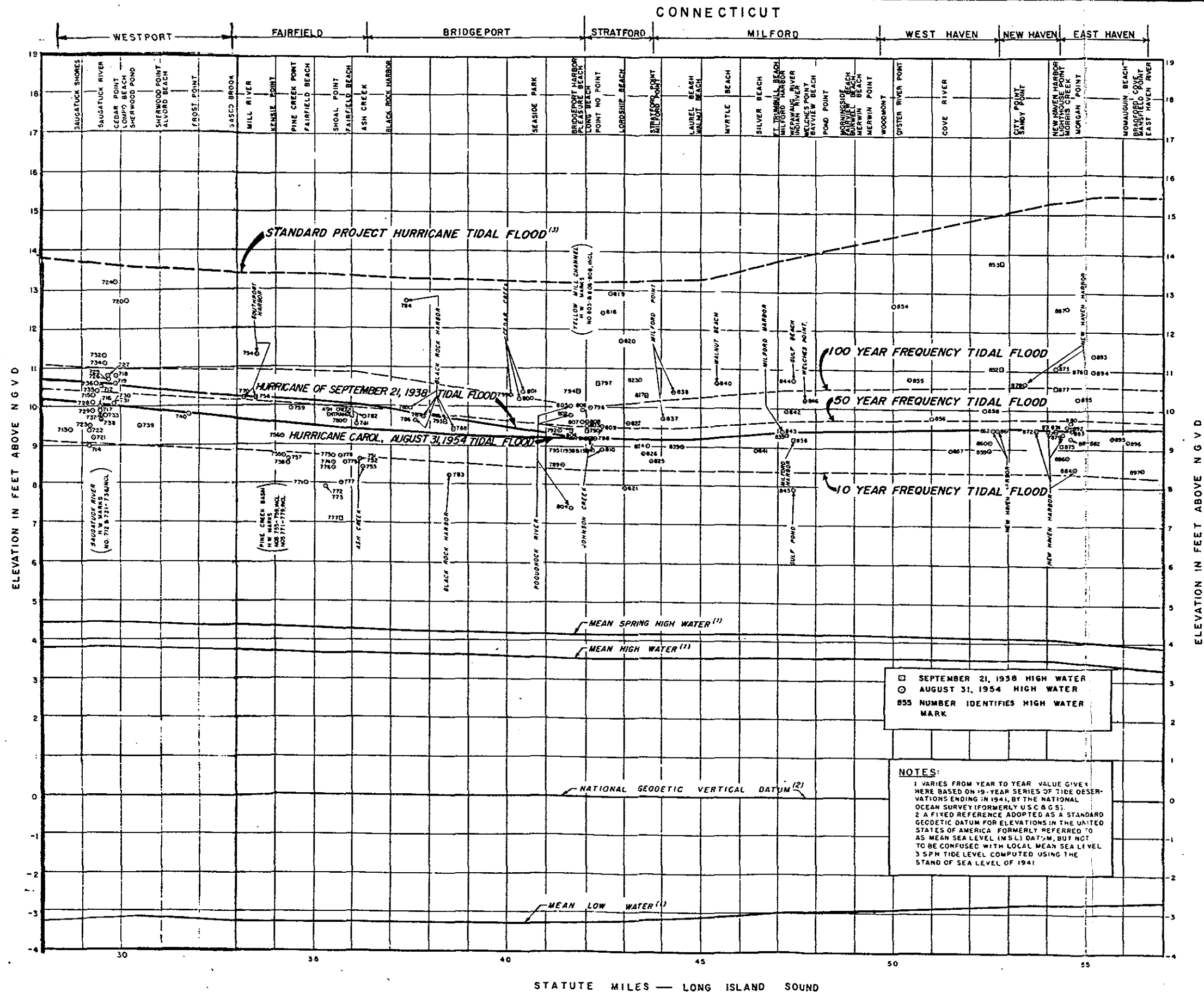
NOTE: Design hurricane tide curve based on Texas A. & M. surge calculations for a design storm with a track most critical to Long Island Sound and with the peak of the surge coincident with the peak of a predicted mean spring tide.

NOTE: Hurricane of September 21, 1938 tide curve based on high water marks in the vicinity of Stratford and hurricane tide at Willets Point, N.Y. stage related to Stratford.

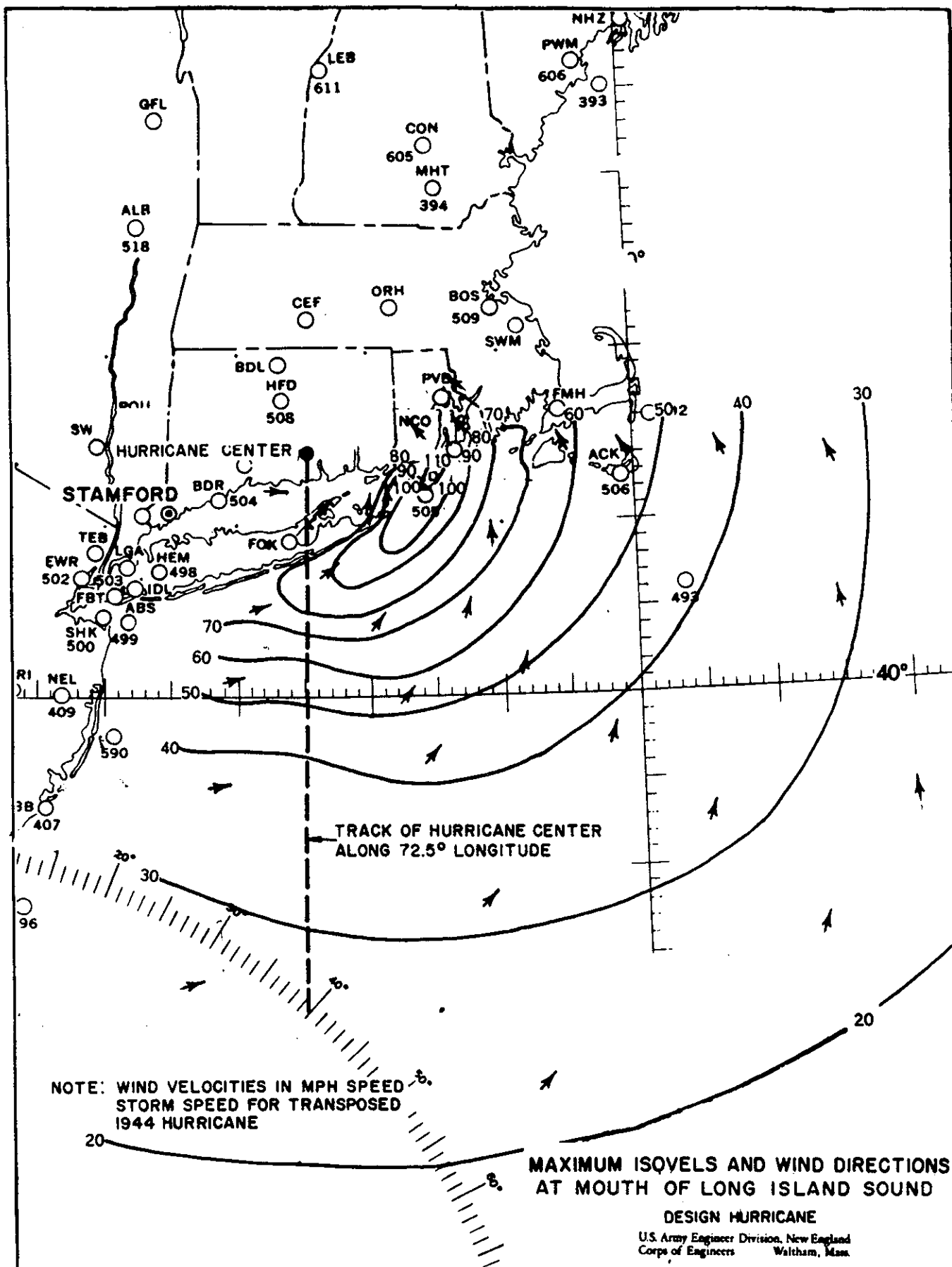
NOTE: Hurricane of September 14-15, 1944 tide curve based on high water marks in the vicinity of Stratford and hurricane tide of New London, Conn. stage related to Stratford.

NOTE: Hurricane Carol, August 31, 1954 tide curve based on high water marks in the vicinity of Stratford and hurricane tide at Bridgeport, Conn. stage related to Stratford.





WEST CENTRAL CONNECTICUT
TIDAL FLOOD STUDY
PROFILE
SEPTEMBER 1987



Appendix C

Economic Analysis

WEST CENTRAL CONNECTICUT TIDAL MANAGEMENT STUDY

HURRICANE PROTECTION FOR:

EAST HAVEN, CONNECTICUT
WEST HAVEN, CONNECTICUT
NEW HAVEN, CONNECTICUT
MILFORD, CONNECTICUT
STRATFORD, CONNECTICUT
FAIRFIELD, CONNECTICUT
WESTPORT, CONNECTICUT

ECONOMIC ANALYSIS

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I. PURPOSE OF STUDY

The purpose of this study is to evaluate the economic benefits of providing hurricane protection to seven communities along the central Connecticut coastline. These areas include: East Haven, New Haven, West Haven, Milford, Stratford, Fairfield and Westport, Connecticut. These communities have been an increase in residential development and land value along their coastline in the last 10 years. It is not uncommon to see homes in the \$500,000-\$1,000,000 range being constructed in areas such as Lordship, or Long Beach in Stratford or Point Beach in Milford. This is the trend in most of the communities in one study area.

As the value of these structures increases, the benefit of protecting the structures also increases. The Federal Emergency Management Agency (FEMA) regulations limit insurance coverage on new construction to those built at a first floor elevation equal to the 100-year flood level. Old structures are covered by FEMA policies which provide for rebuilding but not relocating.

The communities themselves have few laws limiting the density of construction on the coastline which has led to overdevelopment (ie. condominiums) in some areas. Some towns, such as Fairfield, have structure height limitations, but in many cases these can be waived by the local zoning board. A number of structures on Fairfield Beach Road exceed local height limitations.

In lieu of a State or local policy to prevent or limit building on these dynamic coastal areas, the Corps of Engineers was requested by the State to examine the feasibility of hurricane damage reduction solutions to these areas. While several structural solutions were included in the analysis, the study centered on nonstructural solutions such as raising structures or dune

restoration, as these were favored by the State of Connecticut over structural remedies. This economic analysis estimates, on a preliminary basis, the economic benefits to be gained by reducing flood inundation levels in each of the structures susceptible to flood damage.

Economic Analysis

II. DAMAGE SURVEY

During the initial reconnaissance damage survey of the seven coastal Connecticut towns in this study, damage evaluators from the Corps of Engineers visited each site and noted the physical characteristics of each. This process involved recording the number and types of structures, their location in the flood plain, and any new construction partial reconstruction of buildings in the study area. Houses for sale were also identified and realtors were called to determine the range of market prices for these buildings. Random interviews were also conducted with local residents to develop a historical background of the nature and frequency of flooding problems.

At this initial stage, interviews with all residents were impossible because of the time period allowed the analysis. Sample interviews were supplemented in great part with information provided by the assessors office in each town regarding the raw value and square footage of each structure. Each office had a factor which converted assessed value into market value. Building costs per square foot were also obtained to estimate a "rebuild" value for each structure which served as the basis for calculating structural damages.

Structures were identified on flood plain maps. Some towns has very detailed contour maps (some with 2-foot contours) and when these were available structures were located on these maps and these elevations were used. In some cases, there was little local mapping available and FEMA maps were used in conjunction with less detailed contour maps (10-foot contours). Structure elevations were estimated within 10-foot contours by walking the area and using a hand level.

This data was used as input to computer programs developed by HEC to compute annual expected flood damages. The Structural Inventory of Damages (SID) program summarizes the characteristics of each structure, the value of the structure, its contents, first floor elevation and elevation of the various flood events.

The Expected Annual Flood Damage Computation (EAD) uses the damage survey on the SID program to estimate inundation damages associated with specific events (recurring damages) and the damages for each event multiplied by their probability of occurrence and summed (annual expected damages). These computations are carried out for the natural condition and for any alternative plan being considered.

Table 1 is a list of each town, the zones studied for flood damages and a listing of structures within these zones.

TABLE 1
NUMBER & TYPE OF STRUCTURES
IN EACH FLOOD ZONE

	<u>Residential</u>	<u>Commercial/Industrial</u>
<u>East Haven:</u>		
Zone 1: Casey Beach Ave.	564	
Zone 2: South End Pt./Silver Sands	68	
Zone 3: Morris Creek/Shell Beach	133	
<u>West Haven:</u>		
Zone 1: Old Field Creek	143	
Zone 2: Cove River (near Main St.)	52	3
Zone 3: Oyster River	26	13
<u>New Haven:</u>		
Zone 1: Front St. (north of Grand Ave.)	45	3
<u>Stratford:</u>		
Zone 1: Pleasure Beach	43	
Zone 2: Lordship/Long Beach	119	4
Zone 3: Broad St. dike/Ferry Creek		5
<u>Westport:</u>		
Zone 1: Compo Cove/Old Mill Rd.		
Zone 2: Comp Beach	275	1
Zone 3: Saugatuck Shores	159	
<u>Fairfield:</u>		
Zone 1: Fairfield	1,555	
Zone 2: Fairfield Beach Road/SW End	120	
Zone 3: Fairfield Beach Road/Center	62	
<u>Milford:</u>		
Zone 1: Burwells Beach	137	
Zone 2: Cedar Beach & Milford Pt. Rd.	115	
Zone 3: Seaview Ave./Broadway	324	1
Zone 4: Point Beach	248	
Zone 5: Bayview Beach	335	
Zone 6: Milford Harbor (West)		4
Zone 7: Silver Beach	401	
Zone 9: Gulf Pond & Indian River/Rt. 122		10

A. Recurring Losses

Recurring losses are those potential damages which are expected to occur at different flood stages. By integrating stage-damage information obtained during the field damage survey with stage-frequency data provided by hydrologists in Water Control Branch, the probability of those recurrence of different flood losses can be obtained. These relationships are presented for each community in Table 2. These tables are followed by graphs representing damage-frequency for each study area.

TABLE 2

RECURRING DAMAGES

WEST CENTRAL CONNECTICUT TIDAL MANAGEMENT STUDY

EAST HAVEN

Frequency (yr)	Average Stillwater Flood Elevation (ft NGVD)	Damages (\$000)		
		Zone 1	Zone 2	Zone 3
SPH	15.5	14,454	1,486	3,962
500	12.2	6,942	770	1,907
100	10.6	3,429	413	934
50	9.7	1,360	185	390
20	8.9	383	46	100
10	8.3	64	7	15
1	6.3	0	0	0

WEST HAVEN

Frequency (yr)	Average Stillwater Flood Elevation (ft NGVD)	Damages (\$000)		
		Zone 1	Zone 2	Zone 3
SPH	14.7	6,263	5,186	2,298
500	12.3	3,536	2,976	1,306
100	10.6	1,879	1,640	623
50	9.7	1,055	932	281
20	9.0	0	0	15
10	8.4	0	0	0
1	6.7	0	0	0

TABLE 2 (cont'd)

NEW HAVEN

Frequency (yr)	Average Stillwater Flood Elevation (ft NGVD)	Damages (\$000)		
		Zone 1	Zone 2	Zone 3
SPH	15.3	3,085	--	--
500	11.8	1,055	--	--
100	10.5	125	--	--
50	9.8	38	--	--
20	9.1	5	--	--
10	8.5	0	--	--
1	6.4	0	--	--

STRATFORD

Frequency (yr)	Average Stillwater Flood Elevation (ft NGVD)	Damages (\$000)		
		Zone 1	Zone 2	Zone 3
SPH	13.3	1,400	5,890	2,675
500	11.3	662	3,590	1,421
100	10.1	418	2,220	948
50	9.5	203	1,839	778
20	8.8	0	1,133	233
10	8.4	0	518	0
1	6.7	0	0	0

WESTPORT

Frequency (yr)	Average Stillwater Flood Elevation (ft NGVD)	Damages (\$000)		
		Zone 1	Zone 2	Zone 3
SPH	13.6	14,654	34,529	34,074
500	12.1	10,704	20,227	24,745
100	11.0	7,568	4,494	14,201
50	10.3	5,223	1,791	10,145
20	9.6	3,940	1,222	8,373
10	9.0	2,061	662	4,929
1	7.3	0	0	0

FAIRFIELD

Frequency (yr)	Average Stillwater* Flood Elevation (ft NGVD)			Damages (\$000)		
	Zone 1	Zone 2	Zone 3	Zone 1	Zone 2	Zone 3
SPH	13.4	13.4	13.4	277,450	4,600	2,260
500	12.2	12.2	12.2	183,360	3,100	1,540
100	10.6	10.8	10.6	87,120	1,370	870
50	9.7	10.1	9.8	38,629	840	500
20	8.6	9.4	8.8	2,420	150	200
10	7.7	8.8	8.0	0	45	0
1	5.5	7.0	6.0	0	0	0

MILFORD

Frequency (yr)	Average Stillwater Flood Elevation (ft/NGVD)	Damages (\$000)							
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 9
SPH	13.8	5,834	4,914	14,130	9,802	6,233	1,906	15,334	1,281
500	12.0	3,224	3,743	9,150	6,600	4,059	1,198	11,576	724
100	10.5	1,060	2,399	5,349	3,876	2,402	660	7,001	343
50	9.7	73	1,732	3,426	2,808	1,621	347	4,705	39
20	8.9	49	742	1,189	1,847	988	36	1,605	0
10	8.4	22	482	634	1,500	900	0	1,118	0
1	6.7	0	0	0	0	0	0	0	0

* Includes estimated effect of locally constructed flood control improvements.

B. Annual Losses

Table 3 lists the annual expected damages for each site in the project study. The annual damage figure is the summation of all the products derived when each damage figure is multiplied by its corresponding probability of occurrence. These damages are those attributable to water and wave action from flood events but not from high velocity winds.

TABLE 3

<u>Community/Site</u>	<u>Expected Annual Damages</u> (\$000)
<u>East Haven:</u>	
Cosey Beach Ave.	114.27
South End Road/Silver Sands	13.65
Shell Beach	31.29
<u>New Haven:</u>	
Front Street	29.12
<u>Stratford:</u>	
Broad Street/Ferry Creek	38.53
Lordship/Long Beach	153.13
Seaside Park	10.60
<u>West Haven:</u>	
Old Field Creek	57.40
Cove River (near Main St.)	49.62
Oyster River/Route 162	18.25
<u>Milford:</u>	
Burwells Beach	33.22
Point Beach	593.69
Bayview Beach	388.94
Silver Beach	490.52
Seaview Ave./Broadway	305.53
Cedar Beach/Milford Pt. Rd.	196.92

TABLE 3 (cont'd)

<u>Community/Site</u>	<u>Expected Annual Damages</u> (\$000)
<u>Fairfield:</u>	
Zone 1	3680.52
Zone 2	115.39
Zone 3	63.28
<u>Westport:</u>	
Compo Cove/Old Mill Rd.	508.08
Compo Beach	273.15
Saugatuck Shores	1,908.61

III. ALTERNATIVE PLANS AND COSTS

Non-Structural Plan

The non-structural plan that was evaluated for all project sites was the elevation of structures to a first floor height equivalent to the flood height of a 100 yr. frequency storm. This procedure involves jacking the structure up, placing pilings or a concrete foundation underneath, and repairing any structural damage to the building sustained during the procedure. The costs for this construction were developed by questioning contractors in the area who were regularly involved in this activity. During the field effort, many homes in the area were in the process of being elevated, and we were able to speak to contractors directly about the cost and the actual procedure.

The average cost for elevating structures used in the analysis was \$28 per square foot of first floor area.

Structural Plans

Numerous structural plans, ranging from coastal dunes to small road raising projects, were evaluated. All plans, except for the small dune alternative in West Haven, would provide 100 year protection, and have a project life of fifty years. The sand dune at Old Field Creek in West Haven would provide protection against a twenty-five year event and have an estimated project life of twenty-five years.

All alternatives and their first costs are presented in Table 4.

Table 4: Alternatives and First Costs - West Central Ct. Tidal Management Study

<u>East Haven</u>	<u>Alternative</u>	<u>First Cost</u>
Cosey Beach	Raise structures	14,672,000
West Silver Sands Beach	Raise structures	1,904,000
Shell Beach	Raise structures	3,528,000
<hr/>		
<u>New Haven</u>		
Front Street	Raise first floor of structures to 100 yr. storm elevation	1,008,000
<hr/>		
<u>West Haven</u>		
Old Field Creek	A. Raise Structures (100 yr elevation)	3,500,000
	B. Construction of sand dune and berm on the seaside of Beach St. Top Width 201 and bottom width 50" elevation 8.21 NGVD (25 yr. lifetime)	1,430,000
	C. Raising Blohm St. - elevation of 13.6 ft. NGVD (100 yr event) Length 2350 ft. from Noble & Morse to Second Ave.	710,000
	D.1. Construction of Low Dikes top elevation 13.6 NGVD protecting entire flood prone area included: 8900 ft. dike 800 ft. of road raising and 2 flood gates.	2,580,000
	D.2. Protects the majority of flood prone area. It includes 6450 ft. of dike, raising 700 ft. of roadway and 2 flood gates along Blohm Street.	1,980,000
Cove River/Main St.	Raise structures to 100 yr. event elevation	1,540,000
Oyster River/Rt. 162	Raise structures to 100 yr. event elevation	1,092,000
<hr/>		

Milford

Burwells Beach	Raise structures	3,080,000
	Dune & Beach Nourishment	15,300,000
Point Beach	Raise Structures	4,320,000
	Dune & Beach Nourishment	18,700,000
Bayview Beach	Raise structures	4,000,000
	Dune & Beach Nourishment	24,300,000
Ft. Trumbull Beach	Raise Structures	11,230,000
	Dune & Beach Nourishment	15,500,000
Seaview Ave/Broadway	Raise Structures	7,060,000
	Dune & Beach Nourishment	32,300,000
Cedar Beach/Milford Rt. Rd.	Raise Structures	3,220,000

Stratford

Ferry Creek	Raise Road	460,000
Lordship/Beach Dr.	Raise Structures	3,440,000
Long Beach	Raise Structures	1,200,000

Fairfield

Zone 1	Raise Structures	33,870,000
	Dune & Dike Alternative	47,000,000
Zone 2	Raise Structures	2,440,000
Zone 3	Raise Structures	1,320,000
	Dune & Dike Alternative	47,000,000

Westport

Compo Mill Beach		
Old Mill Beach	Raise Structures	2,300,000
Compo Beach	Raise Structures	6,410,000
	Dike	3,200,000
Saugatuck Shores	Raise Structures	7,660,000

IV. BENEFIT ANALYSIS

The benefit analysis estimates the net contribution to national economic development (NED) associated with each proposed protection plan. The annual benefit is measured by subtracting any residual damages associated with a specific plan of improvement from annual expected damage losses associated with the current or natural condition (the without plan condition).

Benefits may be calculated in three categories: (1) inundation reduction benefits, measured as the reduction in flood damages and emergency costs, (2) intensification benefits measured as increase income of existing tenants (industries, businesses) when operations are expanded or modified in some way because of reduction in flooding stages, and (3) location benefits which are "future benefits" to income when land use is made more intensive (i.e. businesses located in an area that previously had flooding problems). The benefit is the difference in anticipated income before and after project implementation. In this analysis, benefits were calculated under the inundation reduction category only, as there is no change in either land use or intensity of use expected in any of the study areas.

Benefits are calculated as the difference between annual expected flood losses associated with the current (or without project) condition and any residual losses associated with each improvement plan. Annual benefits attributable to plans investigated during this study are shown on Table 5, and an economic evaluation of these plans is presented in Table 6.

West	Central Table 5	Tidal Annual	Mgmt. Benefits	Study
		Annual Expected Damages (000's)	Expected Damages w/plan (000's)	Annual Benefit (000's)
East Haven				
Raising Structures				
	Cosey Beach Ave	114.3	29.2	85.1
	W. Silver Sands Bch	13.7	3.1	10.6
	Shell Beach	31.3	8.0	23.3
New Haven				
Raising Structures				
	Front Street	29.1	1.1	28.0
West Haven				
Raising Structures				
	Old Field Creek	57.4	13.2	44.2
	Cove River/ Main St.	49.6	11.0	38.6
	Oyster river/Rt. 162	18.3	4.7	13.5
Dune and Sand Berm				
Beach St.	Old Field Creek	57.4	48.6	8.8
Dike Plan 1				
	Old Field Creek	57.4	13.2	44.2
Dike Plan 2				
	Old Field Creek	54.3	12.6	41.8
Raising Blohm St.				
	Old Field Creek	54.3	12.6	41.8
Milford				
Raising Structures & Dune and Beach Nourishment				
	Burwell's Beach	33.2	12.1	21.1
	Point Beach	593.7	21.4	572.3
	Bayview Beach	388.9	13.6	375.4
	Silver/Ft. Trumbull	490.5	34.9	455.6
	Seaview Ave./Broadwa	305.5	30.7	274.8
	Cedar Bch/Milford Pt	196.9	11.3	185.7
Stratford				
Raising Structures				
	Ferry Creek/Broad St	38.5	5.3	33.2
	Lordship/Beach Dr.	153.1	12.5	140.6
	Long Beach	10.6	2.8	7.8
Raising Broad St.				
	Ferry Creek/Broad St	38.5	0.0	38.5

Table 5 (continued)

Fairfield

Raising Structures

Zone 1	3680.5	575.1	3105.4
Zone 2	115.4	23.3	92.1
Zone 3	63.3	8.1	55.2

Dune & Dike Alternative

Zone 1	3680.5	575.1	3105.4
Zone 3	63.3	8.1	55.2

Westport

Raising Structures

Compo Mill Beach			
Old Mill Beach	508.1	33.2	474.9
Compo Beach	273.2	71.8	201.4
Saugatuck Shores	1908.6	76.8	1831.8
Compo Beach			

Dike Plan

Compo Beach	273.2	71.8	201.4
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West	Central Table 6 -	Ct. Economic	Tidal Evaluation	Mgmt.			
		Number of Structures	First Cost (000's)	Annual Cost (000's)	Annual Benefit (000's)	Benefit Cost Ratio (BCR)	Net Benefits (000's)
East Haven							
Raising Structures							
	Cosey Beach Ave	524	14672	1286.0	85.1	0.07	Negative
	W. Silver Sands Bch	68	1904	166.9	10.6	0.06	Negative
	Shell Beach	126	3508	307.5	23.3	0.08	Negative
New Haven							
Raising Structures							
	Front Street	36	1008	88.4	28.0	0.32	Negative
West Haven							
Raising Structures							
	Old Field Creek	125	3600	315.5	44.2	0.14	Negative
	Cove River/ Main St.	55	1540	135.0	38.6	0.29	Negative
	Oyster river/Rt. 162	39	1092	95.7	13.5	0.14	Negative
Dune and Sand Berm							
Beach St.	Old Field Creek	125	1430	141.2	8.8	0.06	Negative
Dike Plan 1							
	Old Field Creek		2580	226.1	44.2	0.20	Negative
Dike Plan 2							
	Old Field Creek		1980	173.5	41.8	0.24	Negative
Raising Blohm St.							
	Old Field Creek		710	62.2	41.8	0.67	Negative
Milford							
Raising Structures							
	Burwell's Beach	110	3080	270.0	21.1	0.08	Negative
	Point Beach	147	4320	378.6	572.3	1.51	193.682
	Bayview Beach	136	4000	350.6	375.4	1.07	24.79
	Silver/Ft. Trumbull	401	11230	984.3	455.6	0.46	Negative
	Seaview Ave./Broadwa	252	7060	618.8	274.8	0.44	Negative
	Cedar Bch/Milford Pt	115	3220	282.2	185.7	0.66	Negative
Dune & Beach Nourishment							
	Burwell's Beach	110	15300	1341.0	21.1	0.02	Negative
	Point Beach	147	18700	1639.1	572.3	0.35	Negative
	Bayview Beach	136	24300	2129.9	375.4	0.18	Negative
	Silver/Ft. Trumbull	401	15500	1358.6	455.6	0.34	Negative
	Seaview Ave./Broadwa	252	32300	2831.1	274.8	0.10	Negative

Table 6 (continued)

Stratford

Raising Structures

Ferry Creek/Broad St	5	460	40.3	36.7	0.91 Negative
Lordship/Beach Dr.	123	3440	301.5	4.7	0.02 Negative
Long Beach	43	1200	105.2	7.8	0.07 Negative

Raising Broad St.

Ferry Creek/Broad St.		460	40.3	36.7	0.91 Negative
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Fairfield

Raising Structures

Zone 1	1152	33870	2968.7	3105.4	1.05 136.6945
Zone 2	83	2440	213.9	92.1	0.43 Negative
Zone 3	45	1320	115.7	55.5	0.48 Negative

DUNE & DIKE ALTERNATIVE ZONES 1 & 3

	1197	47000	4119.6	3160.9	0.77 Negative
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Westport

Raising Structures

Compo Mill Beach					
Old Mill Beach	60	2300	201.6	474.9	2.36 273.305
Compo Beach	229	6410	561.8	201.4	0.36 Negative
Saugatuck Shores	150	7660	671.4	1831.8	2.73 1160.401

Dike Plan

Compo Beach	229	3200	280.5	201.4	0.72 Negative
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Appendix D

General Non-Structural Methods

APPENDIX D

GENERAL NONSTRUCTURAL METHODS

GENERAL NONSTRUCTURAL METHODS

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GENERAL NONSTRUCTURAL CONSIDERATIONS

FLOODPROOFING MEASURES

Floodproofing, by definition, is a body of techniques for preventing damages due to floods, requiring adjustments both to structures and to building contents, and it involves keeping water out as well as reducing the effects of water entry. Such adjustments can be applied by the individual or as part of a collective action either when buildings are under construction or during remodeling or expansion of existing structures. They may be permanent or temporary.

Floodproofing, like other methods of preventing flood damages, has its limitations. It can generate a false sense of security and discourage the development of needed flood control and other actions. Indiscriminately used, it can tend to increase the uneconomical use of flood plains resulting from unregulated floodplain development.

A floodproofing program would normally warrant serious consideration in the following circumstances:

- . Where floodproofing is the most economically feasible solution;
- . Where flood control projects are not feasible due to environmental or other serious impacts;
- . Where reduced flood risk could lead to more favorable flood insurance rates; and
- . Where existing flood control projects provide only partial flood protection.

Floodproofing measures can be classified into three broad categories. First, there are permanent measures which become an integral part of the structure or land surrounding it. Second, there are temporary or standby measures which are used only during floods, but which are constructed and made ready prior to any flood threat. Third, there are emergency measures which are carried out during flood situations in accordance with a predetermined plan.

Only the first two types of measures will be discussed in the following sections, which will focus on their use in existing structures located in flood hazard areas.

In recent years, floodproofing measures have generally come to be known as "nonstructural" to distinguish them from so called "structural" measures, traditionally associated with major flood control works. The two names are used interchangeably in the presentation of individual types of measures that follow. Although numerous measures exist, depending upon the degree of protection to be provided, the following nonstructural measures are discussed in detail:

- . Installation of temporary or permanent closures for openings in existing structures.

- . Raising of existing structures in place.

- . Rearrangement or protection of damageable property within an existing structure.

- . Relocation of existing structures from a flood hazard area.

- a. Temporary and Permanent Closures For Openings in Existing Structures

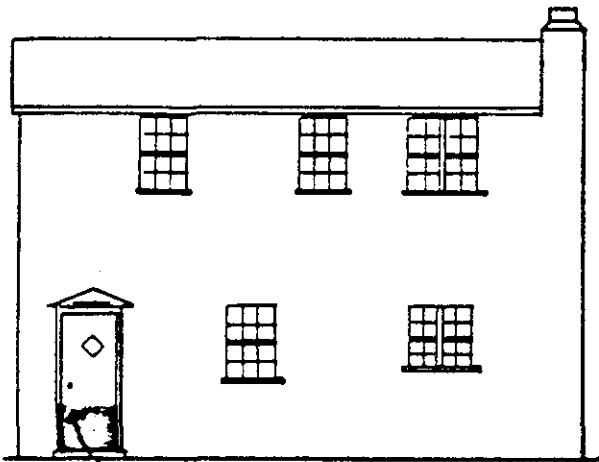
Structures whose exteriors are generally impermeable to water can be designed to keep floodwaters out by installing watertight closures to openings such as doorways and windows as shown on Figure D-1. While some seepage will probably always occur, it can be reduced by applying sealants to walls and floors and providing floor drains where practical. Closures may be temporary or permanent. Temporary closures are installed only during a flood threat and therefore need warning time before installation. Specific measures which may be undertaken are described below.

Doorway Closures - To prevent seepage around exterior doors, installation of some form of floodproofing is required. One of these is flood shields. Shields are normally fabricated of aluminum steel, or wood and made to the height and width desired. In commercial/industrial structures they may be permanently installed on hinges or rollers for swinging or sliding into place or, more often and particularly for residential structures, they may be stored nearby for installation during a time of flood. Doorways not needed may be permanently closed in with masonry or other relatively impermeable materials.

Window Closures - Normal window glass will take little hydrostatic pressure and is especially vulnerable to breakage by floating debris. Flood shields are commonly used to protect windows and prevent water from entering the structure. They may be permanently installed on hinges or rollers at the window opening or stored elsewhere and installed temporarily during floods. Windows not needed can be permanently closed in with masonry or other impermeable materials.

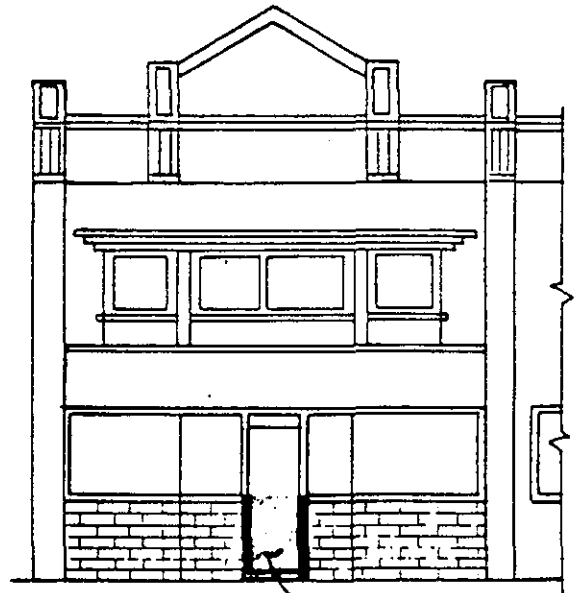
Floodproofing measures such as waterproofing sealants are sometimes applied to generally impermeable floors and walls to further reduce seepage. Sewer lines and other plumbing facilities can be floodproofed by installing backflow valves, gate valves and floor drains equipped with backflow prevention features.

Some seepage is likely to enter a structure even though it is made generally watertight so sump pumps should be available to remove seepage that might occur. The pump discharge should be installed above the expected level of flooding.



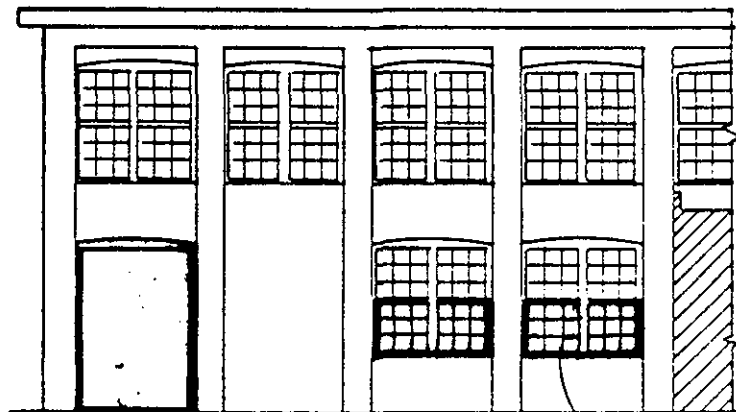
TEMPORARY FLOOD SHIELD
WITH RUBBER GASKET SEAL.

**TWO STORY BRICK
RESIDENTIAL STRUCTURE**



TEMPORARY DOORWAY
FLOOD SHIELD SEATED
AGAINST RUBBER GASKET

ROW STRUCTURE



PERMANENT FLOOD
SHIELD ON HINGES
WITH RUBBER GASKET

TEMPORARY WINDOW SHIELDS
SEATED AGAINST RUBBER GASKETS

COMMERCIAL / INDUSTRIAL STRUCTURE

Temporary and Permanent Closures

The above measures are those generally used to keep water out of a structure. They can be used in any combination depending on specific site conditions.

Physical Feasibility. Most structures, whether residential, commercial or industrial, are not designed to withstand hydrostatic pressure on the exterior walls. Therefore, when discussing physical feasibility the principal considerations are that (1) the exterior walls are impermeable or can be made so, (2) all openings below the design level can be closed, and (3) the structure can withstand anticipated hydrostatic pressures including buoyancy.

Structures with exterior walls constructed of masonry materials are relatively impermeable and can be made more so by sealing exterior surfaces. Such structures are particularly suited to keeping out water and the only adjustments necessary are to minimize seepage through walls and floors with waterproofing materials and closing of doorways, windows and plumbing lines. Structures with sidings of generally permeable materials are difficult to floodproof to the extent of keeping water out. Even for structures constructed of relatively impermeable materials, the condition of the structure and the number, location, and size of opening influence the feasibility of providing closures.

When water is prevented from entering a structure the walls become subject to lateral and hydrostatic forces which may cause buckling or flotation. Most structures are not designed to carry these forces and consequently are in danger of collapse or floating if floodwaters rise too high. It is particularly difficult to analyze the capability of existing structures to resist these forces because of the general lack of knowledge about workmanship and materials used during construction and about the present condition of these materials.

Advantages

- . Floodproofing may be done on a selective basis to only those openings through which water enters and only to the height desired.
- . Easy and quick to implement.
- . For large commercial and industrial type structures, this may be the most important nonstructural means of flood damage reduction.

Disadvantages

- . Applicable only to structure with brick or masonry type walls and without basement, which can structurally withstand the hydrostatic and uplift pressure of the design flood and which are generally watertight.
- . Reduced likelihood of effective closure at nights and during vacations with temporary closures.

- . May create a false sense of security and induce people to stay in the structure longer than they should.

b. Raising Existing Structures

Existing structures in flood hazard areas can often be raised in place to a higher elevation to reduce the susceptibility of the structures to flood damage as shown on Figure D-2.

Physical Feasibility. Technology exists to raise almost any structure. From a practical viewpoint, raising-in-place is most applicable to structures which can be raised by low-cost conventional means. Generally, this means structures that (1) are accessible below the first-floor level, (2) are light enough to be raised with conventional house-moving equipment, and (3) do not need to be partitioned prior to raising. Wood-frame residential and light commercial structures with first floors above grade are particularly suited for raising.

Structures with concrete floor slabs (slab-on-grade) and structures with common walls are not feasible to raise without special equipment involving additional expense.

Advantages

- . Damage to structure and contents is reduced for floods below the raised first floor elevation.

- . Particularly applicable to single and two-story frame structures on raised foundations.

- . Structures have been raised to heights up to nine feet. The greater heights are probably most acceptable in wooded areas of steep topography.

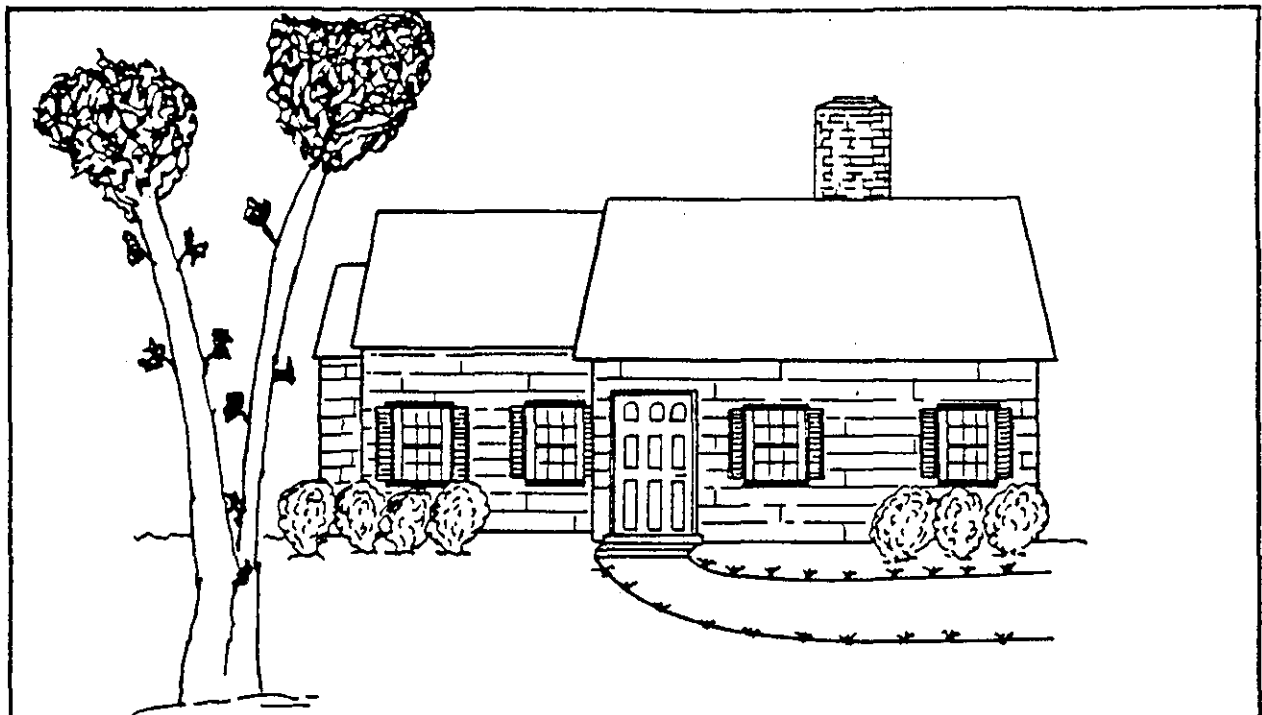
- . The means of raising a structure are well known and contractors are readily available.

- . Raising in-place allows the owner/user to continue living/working at the existing location.

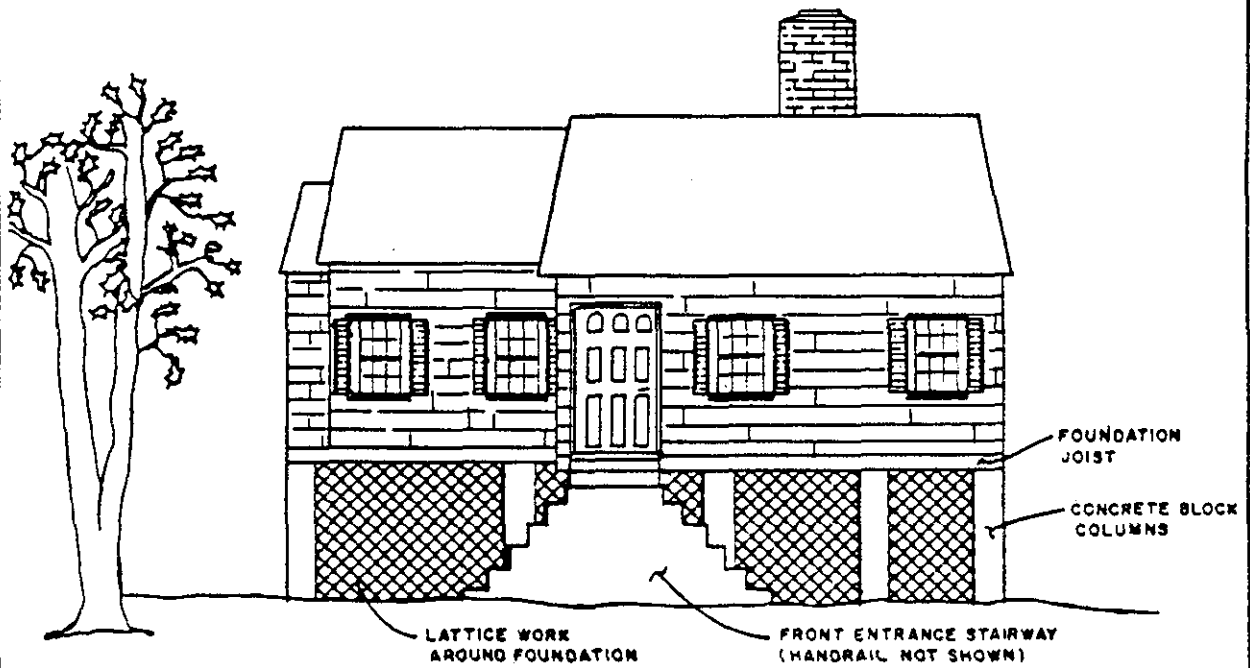
Disadvantages

- . Residual damages exist when floods exceed the raised first floor elevation. Minor damage may occur below the first floor depending upon use.

- . Not generally feasible for structures with slab-on-grade foundations or structures with basements (unless basement flooding is tolerated).



RESIDENCE BEFORE RAISING



RESIDENCE AFTER RAISING

Raising Existing Structure

. Landscaping and terracing may be necessary if the height raised is extensive.

c. Rearranging or Protecting Damageable Property Within an Existing Structure

Within an existing structure or group of structures damageable property can often be placed in a less damageable location or protected in-place. It is something every property owner can do to one degree or another, depending upon the type and location of damageable property and upon the severity of the flood hazard as shown in Figure D-3.

Examples of this type of action are described as follows:

- . Protecting furnaces and appliances by raising them off the floor. This may be appropriate for shallow flooding conditions.
- . Relocating damageable property to higher floors.
- . Relocating commercial and industrial finished products, merchandise and equipment to a higher floor or adjacent and higher buildings.
- . Relocating finished products, materials, equipment and other moveable items located outside a structure to an adjacent, less floodprone site.
- . Protecting commercial/industrial equipment by placing them on a pedestal, table or platform.
- . Anchoring all property which might be damaged by movement from floodwaters.
- . Protecting important mechanical and electrical equipment by inclosing them in a watertight utility cell or utility room.

Physical Feasibility. The degree to which property can be rearranged and protected is site specific. It depends on the flood hazard, principally depth and frequency of flooding; upon the damageable property, its type, value, location and moveability; upon the availability and adaptability of adjacent, less flood-prone locations; and upon whether the rearrangement can be maintained over a succession of flood-free years. Shallow flooding allows the use of protective types of measures where appliances, utilities, equipment and goods can be raised in-place and protected. Where the hazard is more severe and inundation is to greater depths, property will need to be relocated to prevent damage.

Residual damage to both structure and contents will remain even when property is rearranged or protected. For these reasons, protection of property seems to be given most serious consideration when other measures are either not physically or economically feasible or the depth of flooding is relatively shallow.

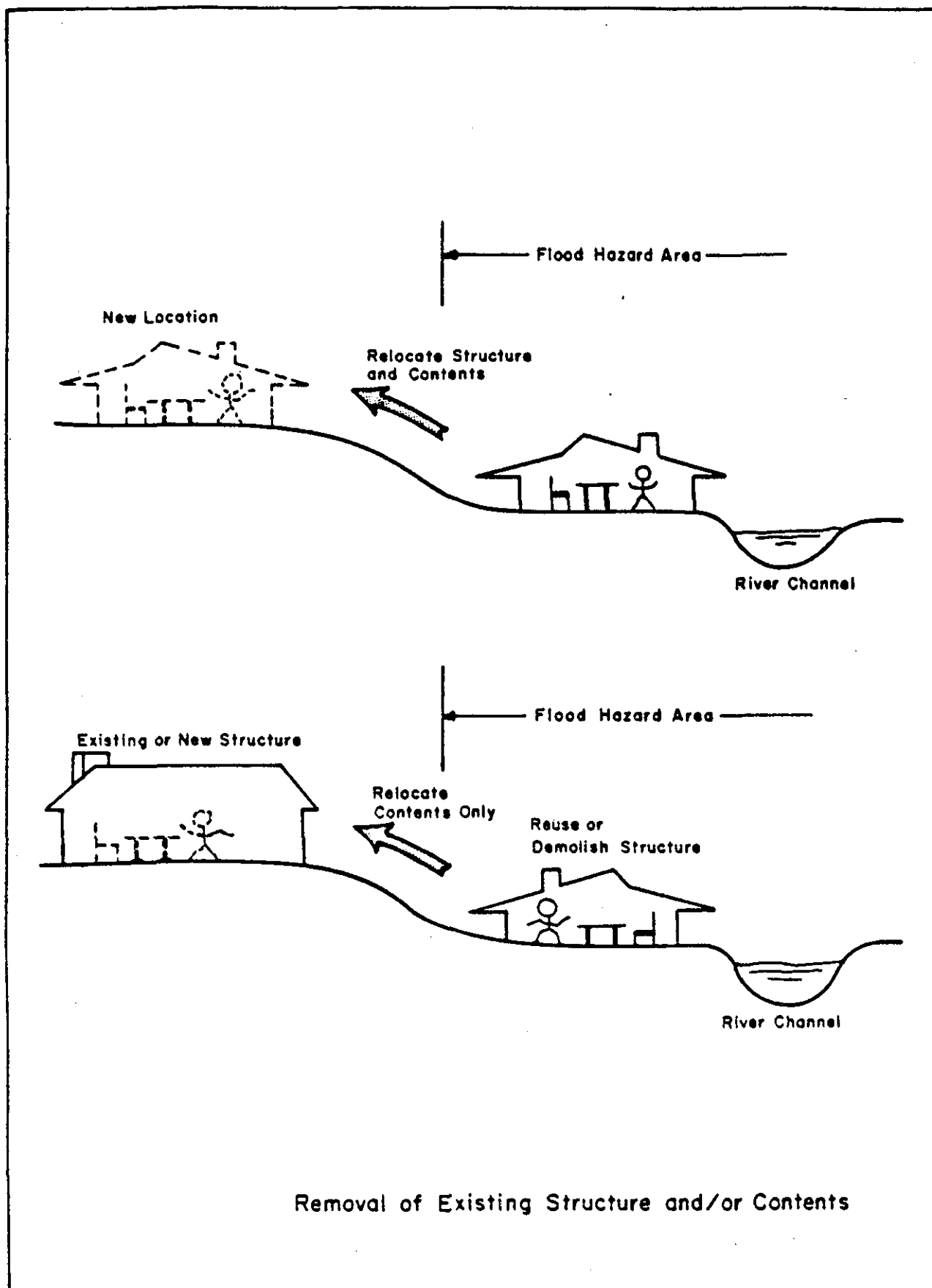


FIGURE D-3

Advantages

- . Most any residential, commercial or industrial property owner can do this to one degree or another.
- . It can be done on a per item basis thus reducing the cost and allowing selective protection of high value contents.
- . A structure can continue to be used at its existing site.

Disadvantages

Damage can be reduced only on those items which can be relocated or protected.

- . A potential residual damage to the structure and contents not relocated or protected remains.
- . New patterns must be established for relocated property.

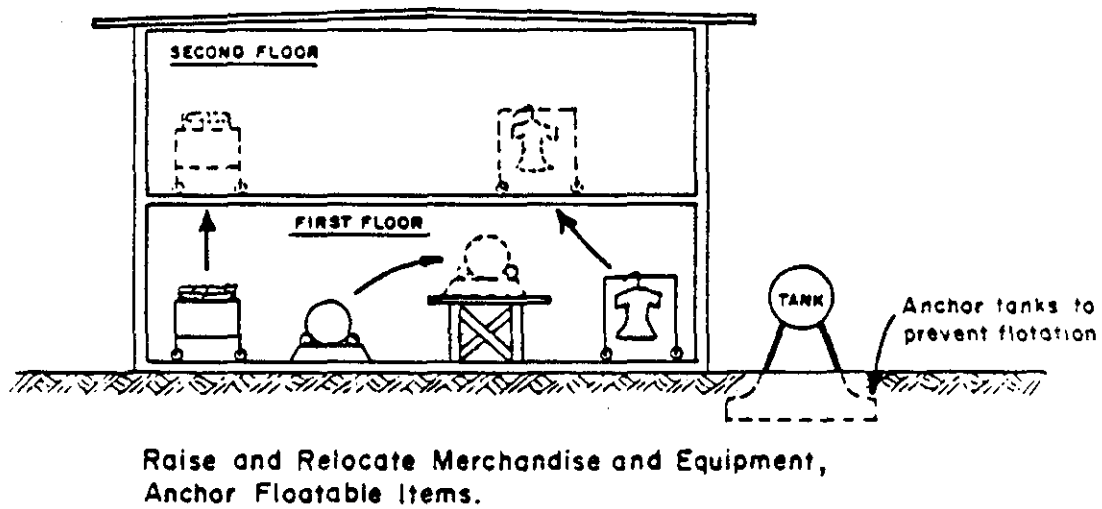
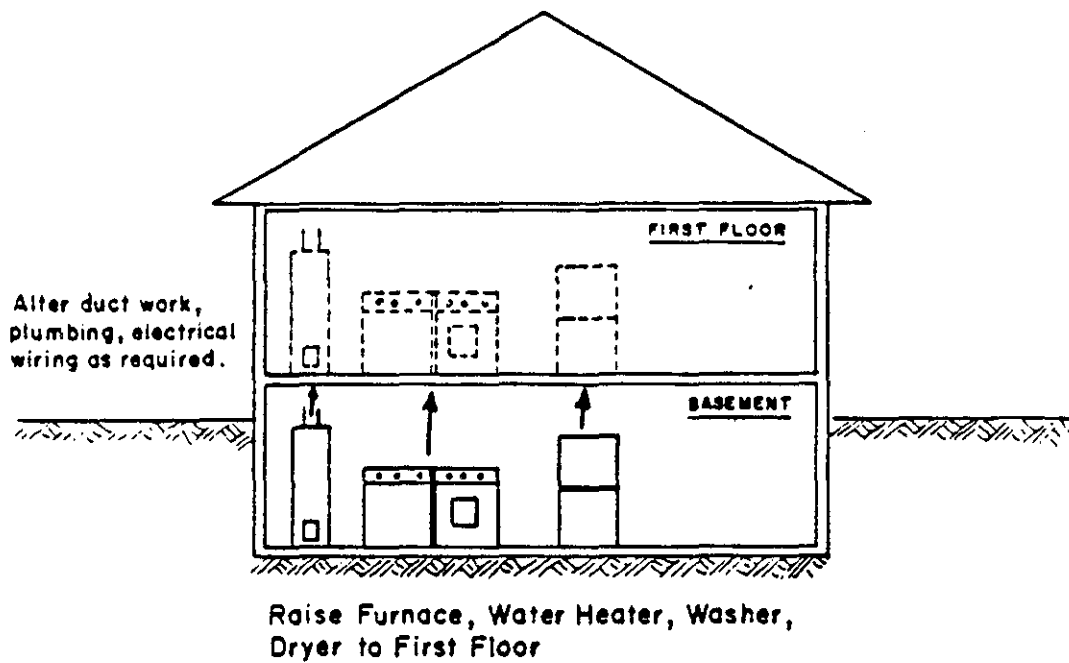
d. Relocation of Existing Structures and/or Contents From a Hazard Area

There are basically two options for removing property to a location outside the flood hazard area. One option is to remove both structure and contents to a flood-free site; the second is to remove only the contents to a structure located out of the flood hazard area and demolish or reuse the structure at the existing site within the flood plain. Each of these options is shown in Figure D-4.

If the structure is reused, it should be for something with contents that are not readily damageable. Preserving a structure for historic purposes is one example. There are also other possibilities such as removing part of the contents, relocating one of a group of structures, or modifying an existing structure to accommodate a new use. In each case the purpose is to remove damageable property from the hazard area, yet take advantage of opportunities for using the existing property in ways which are compatible with the hazard.

Physical Feasibility. While the experience and equipment exist for moving many different types of structures, there is a practical limit on the size and type of structure that is economically feasible to move to reduce flood losses. Even the most readily relocatable structures are costly to remove.

One or two-story residential and light commercial structures of wood frame on raised foundations or basements are usually easy to move because of the structure weight and access to the first floor joists. Structures of brick, concrete or masonry can also be moved; however, additional precautions must be taken to prevent excessive cracking. Most commercial/industrial buildings are not feasible to move because of their



Rearranging or Protecting Existing Property

FIGURE D-4

size and type of construction. Rather than relocate the structure, it is usually more practical to remove the contents and find a new use for it. Similar action is sometimes taken when the damage potential to contents is high, as with valuable merchandise or machinery. In such cases, if the contents cannot be protected in some other way they are often relocated out of the flood hazard area altogether.

The advantages of removing existing contents from a flood hazard area are listed below:

Advantages

- . Flood damage to the existing contents is eliminated. If the structure is demolished potential structural damage is eliminated.

Disadvantages

- . Damage to the structure and site remain if the structure is reused.
- . Costs to remove contents and demolish the structure are high compared to other measures.

The advantages and disadvantages of removing existing structure and contents from a flood hazard area are listed below:

Advantages

- . Flood damage is eliminated because there is no residual damage.
- . Removal allows land use adjustments that may be beneficial to the community.
- . Improved hydraulic performance for passing flood flows.
- . Maintenance of flood plain land may be reduced.

Disadvantages

- . Compared with other measures for existing structures, removal is costly.
- . Advantages associated with being at the flood plain site are lost.
- . The vacated site requires continued maintenance with associated costs.

e. Summary of Floodproofing Measures

Floodproofing, as part of the entire spectrum of nonstructural flood damage reduction measures, has important value when considered as part of a broader program for comprehensive flood plain management. Continued

occupance of developed floodplain sites, and even new development of such sites, may become necessary in some low-lying places, especially in certain urban areas where a shortage of land may offer no realistic alternative. The nonstructural measures for flood damage reduction have an important role alongside traditional structural measures usually associated with major flood control projects.

However, the foregoing general conclusion should not be misunderstood or misinterpreted. Nonstructural measures, like structural measures, have their particular applications and limitations. Each measure must be evaluated for its specific application in the reduction of flood damages and only then can it be decided that the particular measure is feasible, physically and economically.

Some measures could be used exclusively for existing development, others for future; some for residential structures, and others for commercial/industrial buildings; some at locations of frequent flooding, others where it is less frequent.

Lastly, floodproofing and the nonstructural approach to flood loss reduction are not cures for all flood problems. They can increase interest in flood damage reduction programs by heightening public awareness of the flood risk.

FLOOD FORECAST, WARNING AND EVACUATION

Flood forecast, warning and evacuation is a strategy to reduce flood losses by charting out a plan of action to respond to a flood threat. The strategy includes:

- . A system for early recognition and evaluation of potential floods.
- . Procedures for issuance and dissemination of a flood warning.
- . Arrangements for temporary evacuation of people and property.
- . Provisions for installation of temporary protective measures.
- . A means to maintain vital services.
- . A plan for postflood reoccupation and economic recovery of the flooded area.

Flood warning is the critical link between forecast and response. An effective warning process will communicate the current and projected flood threat, reach all persons affected, account for the activities of the community at the time of the threat (day, night, weekday, weekend) and motivate persons to action. The decision to warn must be made by responsible agencies and officials in a competent manner to maintain credibility of future warnings.

An effective warning needs to be followed by an effective response. This means prompt and orderly evacuation of people and property. Actions which can facilitate this include:

- . Establish of rescue, medical and fire squads.
- . Identification of rescue and emergency equipment that can be utilized during a flood.
- . Identification of priorities for evacuation.
- . Surveillance of evacuation to insure safety and protect property.

In addition to evacuation, property can be protected by various measures, temporary flood proofing of structures, use of pumps and flood fighting. For instance flood fighting includes such actions as raising the level of existing protection; closing highways, streets and railroads; preventing backwater in sewers; and protecting against erosion. All of these actions contribute to the overall goal of reducing flood loss.

In addition, a forecast, warning and evacuation strategy will include telephone, energy (gas and electric), sewage, water, traffic control and hospitals as well as police and fire services. Postflood reoccupation and recovery includes:

- . Reestablishment of conditions that will not endanger public health: disease and insect control, safe drinking water, safe sewage disposal, medical supplies.
- . Return of other vital services.
- . Removal of sediment, debris, flood fighting equipment and materials.
- . Repair of damaged structures.
- . Establishment of disaster assistance centers for financial and other assistance.

Factors that determine the physical feasibility of forecast, warning and evacuation measures are somewhat different from those which determine the physical feasibility of many other nonstructural measures, whose feasibility is directly related to the type of structure and depth of flooding. Forecast, warning and evacuation feasibility is more dependent upon hydrologic, social and institutional factors. The selection and feasibility of forecasting capability depends upon the size of the drainage area, whether the river is a main stem or tributary, travel time, and other hydrologic factors that influence the reliability of forecasts. Small watersheds generally have short response times, making it especially

difficult for warnings to be helpful. The feasibility of warning systems also depends upon social factors. One system may be appropriate for one community, but not for another because an infrastructure of community and institutional arrangements is necessary to effectively use hydrologic information. The degree to which this infrastructure is created influences the effectiveness of different warning and evacuation measures.

Advantages

- . Preparedness planning is almost always economically feasible and desirable. Something can usually be done even in areas where other flood loss reduction measures are implemented.
- . A significant saving of lives may result in flash flood or water related structural failure situations.
- . Accurate forecasts and warnings may permit sufficient time to implement temporary protective measures to significantly reduce flood damage.

Disadvantages

- . The effectiveness of the warning system and response of the community cannot be accurately predetermined, consequently neither can potential flood damage reduction.
- . Requires a continuous awareness and information program, maintenance of equipment, etc.
- . Effectiveness of preparedness plans tends to diminish with increasing time between floods.

FLOODPLAIN REGULATIONS

Through proper land use regulation, floodplains can be managed to insure that their use is compatible with the severity of a flood hazard. Several means of regulation are available, including zoning ordinances, subdivision regulations, and building and housing codes. Their purpose is to reduce losses by controlling the future use and changing the existing use of floodplain lands.

Some regulations covering the use of the floodplains are already in effect in the communities within the study area. Regulations may be relatively prohibitive or may allow construction, provided the new structures are floodproofed and/or elevated above a designated flood elevation.

Physical Feasibility. Zoning ordinances, subdivision regulations, and building and housing codes are generally feasible for any floodplain land, whether the land is occupied by residential, commercial or

industrial structures, or by nonstructures such as golf courses and playgrounds. While there are no general limitations, a regulatory program is developed and administered for a specific piece of land in a specific community and State; thus, when developing such regulations at the local level some very real restrictions may develop.

Regulations must be flexible and fair. Procedures for amendments and variances are necessary and can be provided by establishing criteria for special use permits. Also, regulations must be designed to prevent public harm rather than serve public benefits.

Advantages

- . An effective means of bringing about the proper use of floodplain lands. Economic, environmental, and social values can be integrated with the recognized flood hazard.

- . Helps to keep flood damage from increasing. By addressing nonconforming uses they can be helpful in achieving the necessary land use adjustments to mitigate existing flood problems.

- . Can be effective over time on existing improper development or additions and modifications to existing property.

Disadvantages

- . Not effective in reducing flood damage to existing structures.

- . Subject to variance or amendment by local governmental bodies which can reduce effectiveness considerably.

- . Tend to treat all floodplain property equally when in fact various economic factors may make one type of development more appropriate for one portion of the floodplain and another type more appropriate elsewhere.

FLOOD INSURANCE

Flood insurance is not really a flood damage prevention measure as it doesn't reduce damages, rather it provides protection from financial loss suffered during a flood. The National Flood Insurance Program was created by Congress in an attempt to reduce, through more careful planning, the annual flood losses and to make flood insurance protection available to property owners. Prior to this program, the response to flood disasters was limited to the building of flood control works and providing disaster relief to flood victims. Insurance companies would not sell flood coverage to property owners, and new construction often overlooked new flood protection techniques. The insurance program, however, did not come about overnight; it took several attempts and 17 years before the bill was approved and put into effect.

Flood insurance compensates purchasers for losses to the dwelling or business they own and to the contents of these buildings. Flood insurance is an option for all owners of existing buildings in a community approved for the sale of flood insurance, yet it is compulsory for all buyers of existing or new buildings in the Federal Emergency Management Agency (FEMA) designated 100-year floodplain where Federally insured mortgages or mortgages through Federally connected banks are involved.

Qualifying for the National Flood Insurance Program involves a community in two separate phases — the emergency phase and the regular phase. The emergency phase limits the amount of insurance available to local property owners. In this phase, FEMA provides the community with a Flood Hazard Boundary Map that outlines the flood-prone areas within the community. Owners of all structures, regardless of their flood risk, are charged subsidized rates during this phase of the program.

In order to qualify for the Emergency Program, a community must adopt preliminary floodplain management measures including building permits for all proposed construction or other development in the community, which must be reviewed to assure that sites are reasonably free from flooding. The community must also require that all structures in flood-prone areas be properly anchored and made of materials that will minimize flood damage, new subdivisions must have adequate drainage, and new or replacement utility systems must be located and designed to prevent flood loss.

The full amount of flood insurance is available under the regular phase of the program. The amounts charged for insurance of new construction vary in accordance with the structures. Flood plain management efforts of the community become more comprehensive and new buildings must be elevated or floodproofed above certain flood levels. The floodproofing levels are shown on a Flood Insurance Rate Map which is derived from a detailed on-site engineering survey in the community. This map also shows flood elevations and outlines risk zones for insurance purposes.

When the Flood Insurance Rate Map is completed, the community may qualify for the Regular Program by adopting more comprehensive floodplain management measures. Along with the measures adopted for the emergency program, the community must also require that all new construction or any substantial improvements to existing structures be elevated or floodproofed to the level of the base flood. All of the communities in the study area are in the Regular Program.

Advantages

- . Inexpensive to the insured at the subsidized rate.
- . Available to persons in many communities.
- . Indemnification is for any flood up to the limits of the policy.

Disadvantages

- . Only available to persons in communities eligible to participate in the Flood Insurance Program.
- . Indemnification is limited both in magnitude and in type of damage.
- . A deductible provision for each loss makes it somewhat less attractive for low damage flooding.
- . Damages are not reduced.

PUBLIC ACQUISITION OF FLOODPLAIN LAND

Public control over the floodplain may be obtained by purchasing the title or some lesser rights to it such as development rights, right of public access, or rights to use the land in some specified way.

Acquisition of the title is most suited for the undeveloped or sparsely developed land in most of the floodplain. Given the amount of land along the Connecticut coastline this approach has practical limitations. It is a very desirable means, however, of protecting and or providing public access to particularly sensitive or significant areas for environmental, wildlife protection, public open space and recreation or other purposes. Federal and State programs may be enlisted for grant and loan assistance to offset a portion of the cost of acquiring the land. With the amount of protection now available through local flood plain regulations, a program of public land acquisition is not deemed practical at this time.

The acquisition of other interests in land may be an effective instrument to insure that it remains in low intensity uses such as agriculture, tree farms, private camping areas and the like. The means of accomplishment is usually an easement granted or sold to the public agency. Ownership, use, access and occupancy may be retained by the owner, but use is restricted by the terms of the easement. In experiences with this form of land use control it has been found, in some cases, that the purchase of development rights may be almost as expensive as acquiring the full title because the owner's options have been reduced so much. Coupled with tax incentives, however, the technique has a great deal of promise as a floodplain management method.

Costs of acquisition in fee or easement depend upon the cost per acre and number of acres needed. Both items are highly variable and must be determined on a case-by-case basis. Per unit costs can vary considerably within a community, between communities and regionally. The number of acres needed depends upon the plan—it may require a few acres or thousands of acres.

Advantages

- . Provides control of land and its use with fee title.
- . Provides control of certain land uses with an easement, but without the burden of fee title.

Disadvantages

- . Does not reduce existing damage.
- . Requires land management and maintenance by the public owner.

Appendix E

Pertinent Correspondence

APPENDIX E

PERTINENT CORRESPONDENCE

TABLE OF CONTENTS

<u>Correspondent</u>	<u>Date</u>
Arthur J. Rocque, Jr., Director Department of Environmental Protection Planning & Coordination/Coastal Management State of Connecticut	7 June 1988
Joseph L. Ignazio, Chief Planning Division, Corps of Engineers New England Division	11 May 1988
Stanley J. Murphy, Acting Division Engineer LT. Colonel, Corps of Engineers New England Division	29 April 1988
Dawn Maddox Deputy State Historic Preservation Officer Connecticut Historical Commission	16 March 1988
Ronald G. Manfredonia, Chief U.S. Environmental Protection Agency Water Quality Branch	22 October 1987
Gordon E. Beckett, Supervisor U.S. Department of the Interior New England Area	14 October 1987
Stanley W. Gorski, Assistant Branch Chief U.S. Department of Commerce Management Division Habitat Conservation Branch	13 October 1987
Gordon E. Beckett, Supervisor U.S. Department of the Interior New England Area	9 October 1987
Thomas E. Bigford, Branch Chief U.S. Department of Commerce Management Division Habitat Conservation Branch	13 August 1987
Linda S. K. Reed Shoreline Planner Town of Fairfield	8 June 1987

CorrespondentDate

Linda S. K. Reed
Shoreline Planner
Town of Fairfield

18 May 1987

Thomas J. Steinke, Director
Conservation Commission
Town of Fairfield

17 March 1987

Michael Spivak, P.E.
Town Engineer
Town of Stratford

3 March 1987

Stanley J. Pac, Commissioner
Department of Environmental Protection
State of Connecticut

18 February 1987

Thomas J. Steinke, Director
Conservation Commission
Town of Fairfield

9 February 1987

Jacquelyn C. Durrell
First Selectman
Town of Fairfield

17 November 1986

Ronald W. Owens
Town Manager
Town of Stratford

14 November 1986

Thomas W. Bucci, Mayor
Office of the Mayor
City of Bridgeport

13 November 1986

Stephen R. Sasala II, AICP
City Planning Director
City of Bridgeport

10 November 1986

Frances Pierwola, Director
Conservation Commission
Westport Connecticut

7 November 1986

John DeStefano, Jr.
Chief Administrative Officer
City of New Haven

4 November 1986

Gordon E. Beckett, Supervisor
U.S. Department of the Interior
New England Area

4 November 1986

Robert M. Norman, Mayor
Town of East Haven

30 October 1986

Stanley J. Pac, Commissioner
Department of Environmental Protection
State of Connecticut

7 November 1983



STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION
PLANNING & COORDINATION/COASTAL MANAGEMENT



June 7, 1988

Joseph L. Ignazio
Chief, Planning Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254-9149

Dear Mr. Ignazio:

I am writing in response to both your letter to me dated May 11, 1988 and that of Lieutenant Colonel Murphy to Commissioner Carothers dated April 29, 1988 concerning the Draft Reconnaissance Report entitled Tidal-Flood Management. This report evaluates the feasibility of alternative tidal flood management measures at 21 sites in eight communities along the west central portion of Connecticut's coast. It concludes that raising existing structures is economically feasible at 4 sites (2 in Westport and 2 in Milford) and recommends that further studies be conducted. It also concludes that raising structures is economically justified from Kensie Point to Ash Creek in Fairfield, but that raising, strengthening or extending the existing network of dikes should also be studied (no conclusion is reached as to whether this option would be economically justified).

This Department fully supports the concept of raising existing residential structures as a nonstructural flood protection measure. This type of floodproofing generally avoids significant environmental impacts to coastal resources and is consistent with our flood and coastal management policies and state laws. We understand that the additional reconnaissance studies to be performed in Milford and Westport for the purpose of refining the economic analysis of the recommended floodproofing alternative under Section 205 authority would be 100 percent federally funded. We support such an effort. Any future feasibility study and implementation phases would require a cost sharing arrangement and we would expect joint state and local cooperation in meeting the non-federal share.

Because estimated project costs in Fairfield exceed the Section 205 limit, the feasibility study would be conducted under the Long Island Sound Study authority and would require 50 percent non-federal cost sharing. This Department is willing to enter into negotiation of a Feasibility Cost Sharing Agreement for further study of raising existing residential structures in Fairfield. Again, we would expect local cooperation in meeting the non-federal share.

Phone:

165 Capitol Avenue • Hartford, Connecticut 06106

An Equal Opportunity Employer

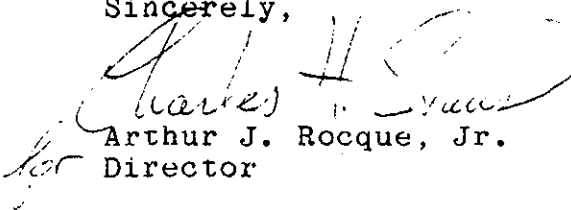
June 7, 1988

With respect to modifying the dikes, although limited information is provided, our knowledge of the Fairfield area leads us to conclude that, in order to provide effective protection from coastal storm events, the various dikes would have to be substantially raised and connected. Given their location adjacent to tidal wetlands and the need to cross currently unrestricted tidal creeks, we are unable to envision how such an effort would not significantly adversely impact coastal resources. If such impacts would be incurred, this alternative would be inconsistent with state law and policy, and perhaps more importantly would be inconsistent with the Corps' own guidelines on implementation of Section 404(b)(1) of the Clean Water Act.

We cannot, at this time, make a commitment to participate in a feasibility study involving the raising, strengthening or enlarging of the existing dikes. We continue to have serious concerns regarding the investigation or proposal of structural flood protection measures that would be inconsistent with state policy. However, we are willing to reevaluate this position at some future date if sufficient information concerning the dikes and potential improvement schemes is provided to allow us to make a preliminary determination that an acceptable project is possible. Any future scope of work negotiated in a Feasibility Cost Sharing Agreement which included the dike-raising element would obviously have to include provisions for environmental assessment of alternatives and the rejection of incompatible structural measures.

I have enclosed a separate sheet which includes suggested substantive and editorial changes to the draft report from the Department staff. If you have any questions concerning these comments or wish to discuss the Department's position on this matter, please contact Dan Rothenberg of my staff at 566-7404 or Chuck Berger of the Water Resource Unit at 566-7244.

Sincerely,


Arthur J. Rocque, Jr.
for Director

AJR/DF/CR

cc: Leslie A. Carothers, Commissioner, DEP
Jacqueline Durrell, First Selectman, Fairfield
Alberta C. Jagoe, Mayor, Milford
Martha Hauhuth, First Selectman, Westport

SUGGESTED CHANGES TO THE
DRAFT RECONNAISSANCE REPORT
TIDAL-FLOOD MANAGEMENT

- Page 14: Should the section titled "Existing Flood Problems" be renamed "Historical Flood Problem"?
- Page 18, Paragraph 3: In addition to items numbered 1, 2 & 3 under the State's flood management efforts, the following should be added: 4) Flood Management for State Agencies Act, 5) Structures and Dredging Act, 6) The Diversion Act and 7) Coastal Area Management Act.
- Page 19, Last Paragraph: The fact that certain structural measures would be inconsistent with State coastal management policies did not appear to affect the Corps decisions as to which alternatives to investigate. Plans inconsistent with State policy could not be supported by this legally empowered non-federal sponsor and should not be supported by the Corps, since Federal consistency could not be demonstrated.
- Page 22, Paragraph 1: The first sentence should be revised to read: Utilization of non-structural measures usually requires a combination of measures to adequately protect activities in a floodplain.
- Page 25, Paragraph 1: The elevations mentioned in the last sentence are determined by FEMA, but new development is required to elevate by local flood management standards.
- Page 26, Paragraph 2: The request to delete Morris Creek was based on the availability of several existing studies of the area and not due to pending legislation.
- Page 29, Paragraph 1: In the second sentence, the creek no longer runs through a wooden culvert at the sandy beach.
- Page 35, Paragraph 2: The premises resulting in elimination of dune restoration and beach nourishment as a feasible alternative in Fairfield should be explained. Were these alternatives only considered as a component of the "comprehensive plan" described in paragraph 3 (see below)? Did dune reconstruction and/or beach nourishment receive benefit/cost evaluations of their own? If so, what assumptions were used to conduct the B/C analysis (e.g. source of sand, cost per cubic yard, construction methods etc.)? In general, we feel information like this should be provided for all alternatives, perhaps as an appendix to the report, so that the reader may understand, generally, what data were used to conduct the analysis.

Page 35, Paragraph 3: Components of the "comprehensive plan" described (i.e. significant diking) are likely to be inconsistent with state flood management and coastal management standards and policies, as well as federal 404(b)(1) guidelines. A statement to this effect should accompany the project description and point out that further consideration of this alternative should not be pursued for these reasons in addition to the negative B/C ratio.

Page 35, Paragraph 4: In our opinion, the screening process for this reconnaissance report should have provided the information necessary to evaluate whether this alternative is worth pursuing. The alternative was introduced quite late in the study, and did not appear to receive even the same level of analysis given to other alternatives. The paragraph describing dike raising, strengthening, or expansion should include recognition of environmental constraints and strong possibility that project would impose unacceptable adverse impacts to tidal wetlands, and would therefore be inconsistent with state flood management policies, coastal management policies and standards, and 404(b)(1) guidelines.

Page 41, Paragraph 3: The last sentence should also include "floodplain management and flood control policies and statutes."



DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02254-9149
May 11, 1988

REPLY TO
ATTENTION OF
Planning Division
Basin Management Branch

Mr. Arthur J. Rocque, Jr.
Director of Planning and Coordination
Coastal Management
Department of Environmental Protection
71 Capitol Avenue
Hartford, Connecticut 06106

Dear Mr. Rocque:

The purpose of this letter is to inform you that our reconnaissance study of tidal flooding along the west central Connecticut coast from East Haven to Westport is essentially complete, and a draft copy of the reconnaissance report is enclosed. Copies of the report have also been forwarded to Mr. Dan Rothenberg of your staff for review within the Department of Environmental Protection.

The investigation of flooding in the eight study area communities determined that further study, focusing on nonstructural solutions, is warranted at five sites. Two of these sites are located in Westport, one in Fairfield and two in Milford. The study process, results and potential recommendations of the study are outlined in the attached letter, which was forwarded to Commissioner Carothers on April 29, 1988.

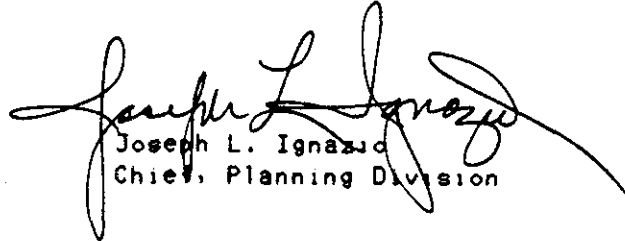
As you are aware, Corps of Engineers studies are being conducted under new rigid time frames. The technical planning study portion of the reconnaissance phase must be completed and submitted to the our Washington office within 18 months. In accordance with this schedule, the reconnaissance report for this study must be submitted by June 9, 1988. Following this submittal, a three month period is allowed for negotiation of the Feasibility Cost Sharing Agreement (FCSA). The FCSA outlines, in detail, the 50-50 cost sharing arrangements to be followed during the subsequent feasibility phase study.

To meet our required June 1988 report submittal milestone, it is requested that your staff review the draft report and submit comments by the end of May 1988. Pending a favorable outcome of this review, it is also requested that a letter supporting further study and your willingness to enter into feasibility cost sharing negotiations be provided to this office prior to the June 1988 milestone. This would allow us to submit our report within the required time frame and proceed to the FCSA negotiation phase. If at some point during the negotiation period continued support for the study could not be provided due to financial or other constraints, support could be withdrawn at that time. A model FCSA and our current feasibility phase cost estimate are included in the draft report as Appendix A. Additional data, including detailed scopes of work, will be developed as the FCSA is prepared and negotiated.

-2-

If you have any questions concerning this letter please contact me at (617) 647-8599, or Mr. Richard W. Heidebrecht, project manager, at (617) 647-8217.

Sincerely,



Joseph L. Ignazio
Chief, Planning Division

Enclosure



DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02254-9149

REPLY TO
ATTENTION OF

April 29, 1988

Planning Division
Basin Management Branch

Ms. Leslie Carothers
Commissioner
Department of Environmental Protection
State of Connecticut
State Office Building
Hartford, Connecticut 06106

Dear Commissioner Carothers:

In the temporary absence of Colonel Rhen, I am writing to inform you of the current status of our Reconnaissance Study of tidal flooding in eight communities along the west central Connecticut coast from Westport to East Haven. The study was authorized as a result of a basic regional plan developed through the Long Island Sound Study which was completed under the direction of the New England River Basins Commission in 1975. This letter also recommends that further study of specifically identified flood problems in the City of Milford and the Town of Westport be conducted under Section 205 of the 1948 Flood Control Act, as amended.

The goal of this Reconnaissance effort was to conduct a preliminary investigation of coastal flood damage within the study area to determine if there is Federal and State interest in the implementation of flood damage reduction measures. The reconnaissance study phase is the first of a two-phase planning process and provides the basis for continuing the study to the feasibility (second) phase. A determination of whether or not planning should proceed further is based on an appraisal of costs, benefits, impacts, and public acceptability of potential solutions. The feasibility phase includes a detailed investigation of alternative solutions, selection of a plan, and results in a report with recommendations to Congress.

As a result of numerous meetings with State of Connecticut DEP officials and representatives of the communities of Westport, Fairfield, Bridgeport, Stratford, Milford, West Haven, New Haven and East Haven, over 30 flood prone sites were originally identified for study. By conducting an initial evaluation of these areas to determine the potential for significant tidal flood damage, the number of sites eligible for Federal participation was reduced to 21. Plan formulation studies in these areas, which included a preliminary assessment of the costs, benefits and impacts of alternative plans, determined that further study is warranted at five sites. These sites are located in the communities of Westport, Milford and Fairfield. The attached schematic delineates the study area and highlights the areas recommended for further study.

Two sites have been identified for further study in the Town of Westport, namely, the Saugatuck Shores area and the low lying area adjacent to Compo Cove. There are approximately 160 structures subject to flooding at Saugatuck Shores and 60 along Compo Cove. Preliminary evaluation of alternative methods to reduce flood damages in these areas determined that floodproofing by raising structures may be economically justified. Structural methods to prevent inundation of these areas were not economically justified.

Evaluation of coastal flooding in Milford determined that further study was justified at the Bayview Beach and Point Beach areas. Formulation of plans to protect approximately 340 structures along Bayview Beach and 250 structures in the Point Beach area determined that structural solutions, such as construction of a coastal dune, would not be economically justified. In addition, the potential environmental impacts of such a plan were considered significant. Further study of floodproofing of structures, however, was found to be justified based on costs and potential impacts.

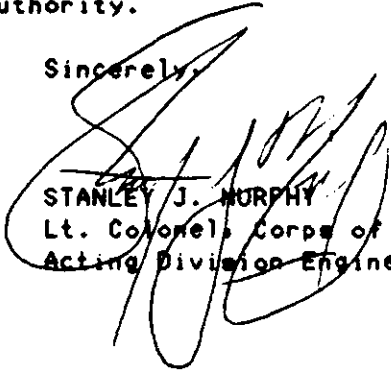
The two sites that were originally identified in the Town of Fairfield were the Ash Creek/Jennings Beach area and the Pine Creek area. Since these sites are contiguous they were subsequently combined into one large study area of over 1200 acres. Studies of potential solutions also determined that raising structures would be economically justified. Coastal projects to prevent inundation of this area, such as dune restoration and construction, were not justified. However, since the Town has constructed some low dikes further inland, particularly to prevent recurring flooding in the Pine Creek area, the possibility of augmenting these protective measures was identified as an alternative that should be evaluated in further detail during the feasibility phase.

The purpose of recommending that further study in the communities of Westport and Milford be conducted under the Section 205 authority is that Congress has granted direct authority to the Corps of Engineers to investigate and construct certain local flood protection projects. The present cost limitation for the Federal portion of this type of project is \$5 million. The current estimate of the Federal portion of the first cost to implement floodproofing measures at each site is within this limit. By proceeding with study under Section 205, this office can be more responsive to the specific needs of each flood prone area. The need for specific Congressional budget action or project authorization for large projects is not required, thereby accelerating further studies and any potential project construction.

Inasmuch as current estimates of project costs in Fairfield exceed the Section 205 limit, feasibility phase studies in this area would be recommended under the Long Island Sound Study authority. As required under the present study authority, further reconnaissance efforts under Section 205 would be 100 percent Federally funded and subsequent detailed feasibility studies would require 50 percent non-Federal cost sharing.

If you concur that further study in Westport and Milford be undertaken under Section 205, please contact my office as soon as possible. This will allow us to complete our reconnaissance study within the required time and include any recommendations to conduct further studies under the Section 205 authority. If you have any questions concerning this letter please contact me at (617) 647-8220 or Mr. Richard Heidebrecht, Project Manager, at (617) 647-8217. For your information and future reference, I have enclosed a copy of our Continuing Authorities Programs booklet which includes a section on the 205 authority.

Sincerely,



STANLEY J. MURPHY
Lt. Colonel, Corps of Engineers
Acting Division Engineer

Enclosures



STATE OF CONNECTICUT
STATE BOARD OF EDUCATION
CONNECTICUT HISTORICAL COMMISSION

March 16, 1988

Mr. Joseph L. Ignazio
Chief, Planning Division
Department of the Army
New England Division, Corps of
Engineers
424 Trapelo Road
Waltham, MA 02254-9149

SUBJECT: West Central Connecticut Tidal Flood Study

Dear Mr. Ignazio:

The State Historic Preservation Office understands that the Corps of Engineers is conducting a reconnaissance study to develop possible alternatives to reduce tidal flooding in coastal communities from East Haven to Westport, Connecticut. This office has reviewed the preliminary cultural resources data compiled by the Corps of Engineers for the area in question. In addition to the well-researched information provided by the Corps of Engineers, this office notes that the project area under consideration in New Haven lies within the Quinnipiac River National Register Historic District. This area is of statewide historic and architectural significance and must be appropriately considered. Moreover, Morse Park in West Haven has been previously surveyed by Connecticut Archaeological Survey, Inc. for archaeological sensitivity. This survey effort resulted in the identification of the inconclusive presence of shell pockets scattered throughout Morse Park.

The 18th-century tidal grist mill in Westport is under consideration by this office's professional staff regarding its National Register eligibility or lack thereof.

The State Historic Preservation Office commends the Corps of Engineers on its comprehensive cultural resources inventory. This office anticipates working with the Corps of Engineers in the evaluation of its preferred alternative(s) vis-a-vis the state's cultural heritage.

For further information, please contact Dr. David A. Poirier, Staff Archaeologist.

Sincerely,

A handwritten signature in cursive script, reading "Dawn Maddox".

Dawn Maddox
Deputy State Historic
Preservation Officer

DAP:nlw



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION I

J.F. KENNEDY FEDERAL BUILDING, BOSTON, MASSACHUSETTS 02203-2211

October 22, 1987

Mr. Joseph L. Ignazio, Chief
Planning Division
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Dear Mr. Ignazio:

Thank you for the opportunity to comment on the reconnaissance study undertaken by your office examining methods to minimize flood damage along the west central Connecticut coast. While EPA was not able to attend the field visits to the affected towns of Westport, Fairfield, Stratford, Milford, West Haven, New Haven, and East Haven, Sue Brown of your staff has provided us with information on the various options you are considering.

We are encouraged by the non-structural alternatives that are being considered in this study. Floodproofing structures, flood warnings and evacuation, and raising structures clearly all have negligible effects on sensitive coastal ecosystems when contrasted with historically more prevalent structural "solutions" to flood damage problems. Certainly EPA prefers these alternatives based on their minimal environmental impact.

The Corps is considering dike erection at two sites, Compo Beach in Westport and Old Field Creek in West Haven. Both dikes appear to have the potential to fill portions of coastal marsh and to alter drainage and hydrological patterns of these important coastal communities. While the West Haven dike would enclose a Phragmites australis dominated marsh as opposed to a Spartina spp. marsh, the potential for this area to support a future Spartina marsh would likely be jeopardized. Additionally, piping plovers which nest in the vicinity of the Old Field Creek site could be disturbed by both the proposed dike as well as the elevation of First Avenue/Beach Street. For these reasons, EPA recommends against these structural flood damage control techniques in Westport and West Haven.

The six sites in Milford being examined in this study are considered for beach nourishment or dune restoration. Piping plovers (listed as threatened) nest within a portion of the Cedar Beach/Milford Point study area, and can potentially nest elsewhere in Milford in similar sandy, sparsely vegetated coastal habitat. Beach nourishment in Milford could eliminate nesting habitat currently being used by the birds. EPA recommends against this alternative at this time, given the current uncertain impacts on the plovers.

Please contact Tom Addison of my staff (FTS 835-4428) for further coordination on this project.

Sincerely,

A handwritten signature in dark ink, appearing to read 'R. Manfredonia', with a long horizontal flourish extending to the right.

Ronald G. Manfredonia, Chief
Water Quality Branch

cc: Gordon Beckett, USFWS, Concord, NH
Michael Ludwig, NMFS, Milford, CT
Richard Huntley, CT DEP, Hartford, CT



United States Department of the Interior

FISH AND WILDLIFE SERVICE
400 RALPH PILL MARKETPLACE
22 BRIDGE STREET
CONCORD, NEW HAMPSHIRE 03301-4901

Mr. Joseph L. Ignazio
Chief, Planning Division
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254-9149

OCT 14 1987

Dear Mr. Ignazio:

This responds to your September 11, 1987 request for information on the presence of Federally listed and proposed endangered or threatened species in the area of your proposed tidal flood damage reduction study along the west central Connecticut Coast. Your letter specified the areas under consideration to include portions of the Townships of Westport, Fairfield, Bridgeport, Stratford, Milford, West Haven, New Haven and East Haven, within the 100-year flood plain. As a result of information provided by your staff (September 25), it is our understanding that the Bridgeport site is no longer being considered as part of your study and for that reason is not addressed in this response.

Several of your proposed project areas are in the vicinity of nesting sites for the Federally listed threatened Piping Plover (Charadrius melodus). These sites are as follows: Long Beach and Short Beach, Stratford; Milford Point, Milford; and Sandy Point, West Haven. Of these sites it would appear that only the Milford Point, Milford and the Sandy Point, West Haven nesting areas have the potential to be affected, dependent largely on the type of flood reduction alternative selected.

The Milford Point Plover nesting site lies within the western boundary of your Milford study area, while the Sandy Point site is outside of but close to your Old Field Creek, West Haven area. It should also be noted that effects to Plover recovery could result should modification to potential beach habitat occur. Because of this, we recommend you maintain contact with our endangered species staff as project plans progress in order to assess the need for initiation of formal Section 7 consultation.

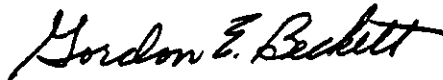
This response relates only to endangered species under our jurisdiction. It does not address other legislation or our responsibilities under the Fish and Wildlife Coordination Act.

You may wish to contact Rita Duclos of the Connecticut Department of Environmental Protection at 203-584-9830 for information on state listed species.

-2-

A list of Federally designated endangered and threatened species in Connecticut is inclosed for your information. Thank you for your cooperation and please contact Roger Hogan of my staff at 603-225-1411 if we can be of further assistance.

Sincerely yours,

A handwritten signature in cursive script that reads "Gordon E. Beckett".

Gordon E. Beckett
Supervisor
New England Area

Inclosure

FEDERALLY LISTED ENDANGERED AND THREATENED SPECIES
IN CONNECTICUT

Common Name	Scientific Name	Status	Distribution
<u>FISHES:</u>			
Sturgeon, shortnose*	<u>Acipenser brevirostrum</u>	E	Connecticut River & Atlantic Coastal Waters
<u>REPTILES:</u>			
Turtle, green*	<u>Chelonia mydas</u>	T	Oceanic straggler in Southern New England
Turtle, hawksbill*	<u>Eretmochelys imbricata</u>	E	Oceanic straggler in Southern New England
Turtle, leatherback*	<u>Dermochelys coriacea</u>	E	Oceanic summer resident
Turtle, loggerhead*	<u>Caretta caretta</u>	T	Oceanic summer resident
Turtle, Atlantic ridley*	<u>Lepidochelys kempii</u>	E	Oceanic summer resident
<u>BIRDS:</u>			
Eagle, bald	<u>Haliaeetus leucocephalus</u>	E	Entire state
Falcon, American peregrine	<u>Falco peregrinus anatum</u>	E	Entire state-reestab- lishment to former breeding range in progress
Falcon, Arctic peregrine	<u>Falco peregrinus tundrius</u>	E	Entire state migratory- no nesting
Plover, Piping	<u>Charadrius melodus</u>	T	Entire State - nesting habitat
<u>MAMMALS:</u>			
Cougar, eastern	<u>Felis concolor couguar</u>	E	Entire state - may be extinc
Whale, blue*	<u>Balaenoptera musculus</u>	E	Oceanic
Whale, finback*	<u>Balaenoptera physalus</u>	E	Oceanic
Whale, humpback*	<u>Megaptera novaeangliae</u>	E	Oceanic
Whale, right*	<u>Eubalaena</u> spp. (all species)	E	Oceanic
Whale, sei*	<u>Balaenoptera borealis</u>	E	Oceanic
Whale, sperm*	<u>Physeter catodon</u>	E	Oceanic
<u>MOLLUSKS:</u>			
NONE			
<u>PLANTS:</u>			
Small Whorled Pogonia	<u>Isotria medeoloides</u>	E	Hartford, New Haven, Fairfield, New London, Windham, Tolland, Litchfield Counties

* Except for sea turtle nesting habitat, principal responsibility for these species is vested with the National Marine Fisheries Service

FEDERALLY PROPOSED ENDANGERED AND THREATENED SPECIES
IN CONNECTICUT

Common Name	Scientific Name	Status	Distribution
Roseate Tern	<u>Sterna dougallii</u> <u>dougallii</u>	Proposed as Endangered 11/4/86	Atlantic Coast

Determination that these species are endangered would make them eligible for the protection provided by Section 7 of the Endangered Species Act of 1973, as amended. Proposed species are offered limited protection under Section 7(a)(4), which requires Federal agencies to confer with the Service on actions which may jeopardize the proposed species.

Rev. 7/6/87



UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

Management Division
Habitat Conservation Branch
Sandy Hook Marine Laboratory
Highlands, New Jersey 07732

October 13, 1987

Ms. Susan Brown
Environmental Branch
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254-9149

Dear Ms. Brown:

We have reviewed the information you provided regarding the West Central Connecticut Tidal Flood Reduction Study. Investigations clearly indicate that the project, as presently proposed, will have no direct, adverse impacts to the resources for which our agency is responsible.

The Army Corps of Engineers has responsibility under Section 7 of the Endangered Species Act to consult with the National Marine Fisheries Service (NMFS) regarding certain endangered or threatened species. We have identified the presence of no endangered or threatened species which come under the jurisdiction of the NMFS in the project area. Should project plans change, or if additional information on currently listed species or species proposed to be listed becomes available, this determination may be reconsidered.

Should you wish to discuss this matter further, please contact Michael Ludwig at (FIS) 642-5200.

Sincerely,

Stanley W. Gorski
Assistant Branch Chief





United States Department of the Interior

FISH AND WILDLIFE SERVICE
400 RALPH PILL MARKETPLACE
22 BRIDGE STREET
CONCORD, NEW HAMPSHIRE 03301-4901

Mr. Joseph Ignazio, Chief
Planning Division
New England Division
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254

OCT 9 1987

Dear Mr. Ignazio:

This Planning Aid letter is intended to provide a preliminary assessment of potential impacts on fish and wildlife resources of various alternatives evaluated by the New England Division during your flood damage reduction reconnaissance study along a portion of the west central Connecticut coast. It is submitted in accordance with the Fish and Wildlife Coordination Act, 16 USC 661 et seq.

The study area included the Townships of Westport, Fairfield, Stratford, Milford, West Haven, New Haven and East Haven. Specific flood prone sites within the 100-year floodplain in each town were assessed to determine which of several alternatives would best serve to reduce tidal flood damage. Only the alternatives which have the potential for impacting significant resources in the study area will be addressed here; consequently, alternatives such as flood proofing structures and providing flood warnings will not be specifically addressed although they would be among Fish and Wildlife Service's preferred alternatives because of their lack of impact.

Alternatives considered include dikes, beach nourishment and dune reconstruction, and raising structures on pilings. Sites and alternatives considered are shown below.

<u>Study Sites</u>	<u>Alternatives*</u>		
	DI	BN	RS
East Haven (3)			X
New Haven (1)			X
West Haven (3)	X		X
Milford (6)		X	X
Stratford (2)			X
Fairfield (2)			X
Westport (4)	X		X

*DI - dike

BN - beach nourishment/dune restoration

RS - raise structures

Significant Resources in the Study Area

Milford Point (Connecticut Audubon Society Sanctuary) located at the mouth of the Housatonic River in Milford, is a barrier beach which juts out into Long Island Sound. On the north side of the beach is the 840-acre Nell's Island Saltmarsh and on the south, are mud flats which are known as the best shorebird areas in the state. Over 230 bird species are known to occur in the two areas including the Piping Plover (Charadrius melodus) a Federally listed threatened species which nests on the point, and the Roseate tern (Sterna d. dougallii) a Federally proposed endangered species which uses the area during fall stopovers. In Stratford, west across the Housatonic is Long Beach, bordered on the north by the extensive Great Meadows saltmarsh. This beach also serves as an area of extensive shorebird use including use as a nesting area for the Piping Plover. Short Beach, east of this location also serves as a plover nesting area. In West Haven, in the western part of New Haven Harbor is located Sandy Point, a barrier beach which serves as a roosting area for numerous species of shorebirds and as a Piping Plover nesting area. In this general area, over 35 species of shorebirds have been recorded.

Extensive saltmarshes occur throughout the study area as noted above. It is worthy of mention that there is a growing interest in the restoration of the marshes both by municipal and state organizations. A prime example is the work being done by the Town of Fairfield to restore a Phragmites marsh at Pine Creek/Wakeman Island to a natural tidal saltmarsh Spartina assemblage through the breaching of a restrictive dike. Significant progress has been made with Spartina making a strong comeback.

POTENTIAL RESOURCE IMPACTS

DIKE CONSTRUCTION

Westport - Compo Beach

The Compo Beach site is one of two sites where dike construction is being considered. The plan calls for essentially encircling a low-lying area of homes north of the yacht basin bordered by Compo Beach Road on the south and west, Soundview Drive on the east and Compo Road south, on the north, by a dike. The dike ranging in height from 2.5 - 5.0 feet high and approximately 4800 feet long, would be built along the east, west and south roads (mentioned above) which border the low-lying area.

Of concern are impacts to the Grays Creek saltmarsh area which forms the west boundary of the project. As planned the longest stretch of flood control dike would encroach on the eastern edge of this Spartina marsh. Construction

impacts, the permanent intrusion of a dike projected to be approximately 20 feet wide at the base and possible alteration of natural run-off patterns could cause significant impacts to this coastal resource. We, therefore, recommend that the dike plan be dropped in favor of a less disruptive alternative.

West Haven - Old Field Creek

The Old Field Creek site is the only site, other than Westport, where a structural solution to tidal flooding is being considered.

Old Field Creek flows through the center of a coastal Phragmites marsh, across a sandy beach area and into New Haven Harbor/Long Island Sound. Homes seeking flood protection are "inserted" into the marsh along its borders. The proposed dike would essentially be placed in the backyards of these homes and border the marsh on its north, east and west sides. Beach Street crosses over Old Field Creek to the south and serves as a border to the marsh. It is proposed to raise the section of the street east of Old Field Creek (Beach Street/First Avenue) approximately 2.0 to 4.3 feet to serve as a 4400 foot barrier to floodwaters from the sound. The proposed dike, to be placed on the marsh borders would be approximately 4.74 feet high and 7600 feet in length. Width at the base would be approximately 20 feet, most of which would likely be in the marsh. It is our understanding that the state is considering restoring this marsh.

Two major resource impact concerns exist for this site; impacts to the marsh and potential disturbance to nesting piping plovers, a Federally listed threatened species, occupying a beach nesting area at the base of Sandy Point, southeast of the project site. The Sandy Point area is also occupied by Least Terns (Sterna antillarum) a species of state and regional interest, and other shorebirds.

Potential impacts to the marsh would include those associated with dike construction and permanent encroachment and modification of natural run-off patterns. These potential impacts could also be caused by the raising of Beach Street, although these may be of lesser magnitude.

Five pairs of Piping Plovers nested at the Sandy Point location in 1987, and produced 8 young. Only 24 pairs of these shore birds nested in Connecticut.

Potential impacts to these birds would be disturbance associated with modification of Beach Street and construction of the southeastern portion of the proposed dike.

Because of the resource impacts described above, we recommend that this alternative be dropped from consideration.

BEACH NOURISHMENT/DUNE RESTORATION

Milford

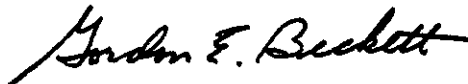
Data provided by NED indicate the beach nourishment/dune restoration alternative is currently being considered for the 6 Milford sites. In Milford the Piping Plover nests on Milford Point within the western boundary of the Cedar Beach/Milford Point study site, and is known to have the potential to nest at other beach sites in the area. In general, the plover "prefers" nesting at sites on open, sandy shores which have little or no vegetation. Preferred locations are large open spaces at the tips of growing sand spits and on barrier beaches. Because of its preference for nesting in "disturbed" habitat, largely free of vegetation, the beach nourishment/dune restoration alternative has the potential to impact the plover through the elimination of potential nesting habitat. For this reason we recommend against use of this alternative. In addition, it is possible that sand added to beach areas could impact shellfisheries through transport and deposition on beds. Ascertaining the degree of this potential impact would require site population surveys.

RAISING STRUCTURES

This alternative should result in essentially no measurable resource impacts at any sites where it is being considered if adherence to appropriate state and Federal regulations is maintained.

If you should have any questions concerning this letter, please feel free to contact Mr. Roger Hogan of this office at 603-225-1411 or FTS 834-4411.

Sincerely yours,



Gordon E. Beckett
Supervisor
New England Area

CC: RO/FWE Reading File
EPA, D. Thompson
NMFS, M. Ludwig
CT DEP-
Rita Duclos,
Tom Ouellette
ES: RHogan:gl/jd:10-8-87:834-4411



UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

Habitat Conservation Branch
Management Division
2 State Fish Pier
Gloucester, MA 01930-3097

August 13, 1987 F/NER74:TEB

Joseph L. Ignazio
Chief, Planning Division
New England Division, Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Dear Mr. Ignazio:

Thank you for inviting the National Marine Fisheries Service to join NED's efforts to develop tidal flood damage reduction measures for parts of the Connecticut coast. We encourage reconnaissance and feasibility studies of solutions to flooding from storms and tides. NMFS also urges a long-term perspective since many coastal projects will witness greater oceanic pressures from rising sea levels over the coming decades.

Our point of contact on these activities will be Mike Ludwig, located in our Milford, CT office (FTS 642-5213).

Sincerely,

Thomas E. Bigford
Branch Chief





Town of Fairfield

FAIRFIELD, CONNECTICUT 06430

TOWN PLAN AND ZONING COMMISSION

June 8, 1987

Mr. Douglas Cleveland
Army Corps of Engineers
Department of the Army
424 Trapelo Road
Waltham, MA 02254

Dear Mr. Cleveland:

On behalf of the Town of Fairfield's Shoreline Advisory Committee, thank you for participating in our special program on "Rising Sea Level - An Engineering Approach". Your participation in last week's meeting helped emphasize the need for coastal communities to plan for the anticipated rise in sea level. Your explanation of the Corps' present review of coastal flooding in southwest Connecticut was brief but comprehensive and most certainly of great interest to the audience.

Perhaps you can continue to help us with our coastal planning efforts by keeping me informed of the Corps' developing policy on rising sea level.

Again, your participation in this program is sincerely appreciated. We look forward to working with you on the coastal flooding project.

Very truly yours,

SHORELINE ADVISORY COMMITTEE

A handwritten signature in dark ink, appearing to read "Linda S. K. Reed", is written over the typed name.

Linda S. K. Reed,
Shoreline Planner

LKR:mpw



Town of Fairfield

FAIRFIELD, CONNECTICUT 06430

TOWN PLAN AND ZONING COMMISSION

May 18, 1987

**Mr. Doug Cleveland
US Army Corps of Engineers
Basin Management Branch
424 Trapelo Road
Waltham, MA 02254**

Dear Mr. Cleveland:

I hope that your visit to the Town of Fairfield's coastal area earlier this month was helpful to you and your project associates. The Town is very interested in the prospect of learning more about storm damage estimates and techniques to potentially reduce storm impacts. Please keep us posted on the feasibility of the Corps doing this study.

To help further familiarize you and your associates with Fairfield's shore, I am enclosing the materials which I described. I hope that you find this material useful.

Please do feel free to call us if you have any questions.

Sincerely,

TOWN PLAN AND ZONING

**Linda S.K. Reed,
Shoreline Planner**

LKR:1kr

Enc.

CONSERVATION COMMISSION
THE WETLANDS AGENCY
THOMAS J. STEINKE, DIRECTOR



Independence Hall
725 Old Post Road
Fairfield, Connecticut 06430
Tel. 203 255-8267

Town of Fairfield

March 17, 1987

Mr. Douglas Cleveland
U.S. Army Corps of Engineers
Coastal Study
424 Trapelo Road
Waltham, MA 02154

Dear Mr. Cleveland:

Thank you for the opportunity to review your program proposal for studying coastal flood problems and their alternative solutions in Fairfield.

I am enclosing a copy of a proposal to restore the form and function of Penfield Peninsula because it has pertinence to flood control issues. I hope it proves useful to you at least as background information to geological shoreline development.

Please keep me apprised of your progress in this study and do not hesitate to call if I can be of any further assistance.

Sincerely,

Thomas J. Steinke

TJS:pas
Enclosure
cc: Jacquelyn C. Durrell, First Selectman



TOWN OF STRATFORD

CONNECTICUT

OFFICE OF THE TOWN ENGINEER
385-4015

March 3, 1987

Mr. Douglas Cleveland
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254

Dear Mr. Cleveland:

Enclosed are the relevant sections of the Economic Evaluation of Alternatives Ferry Creek Storm Water Pump Station and the Ferry Creek, Bruce Brook Drainage Basins Storm Water Study that you requested.

If we can be of any further assistance to you, please call the Engineering Office at 385-4015.

Very truly yours,

Michael Spivak, P.E.
Town Engineer

MS:fp
Enc.



"COUNCIL-MANAGER GOVERNMENT SINCE 1921"



STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION



COASTAL AREA MANAGEMENT PROGRAM

February 18, 1987

Colonel Thomas Rhen
Division Engineer
U. S. Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254

RE: Corps Flood Reconnaissance Study - Westport to East Haven, CT

Dear Colonel Rhen:

In October of 1986, we received a letter from the Basin Management Branch or your Planning Division indicating their intent to initiate the reconnaissance study noted above. Although staff from the Department of Environmental Protection (DEP) have met with representatives from the Corps twice since the initiation of the study, we are concerned about the direction that this project appears to be taking. Specifically, our concerns are as follows:

1. It is not clear that this study is in response to the Department's 1983 request. Although this request was discussed in detail with the Planning Division in 1983 and 1984, the present reconnaissance study does not appear to match either the intent or the target municipalities of our request.
2. There has been very little coordination with the Department on the development of a scope of work for this study or in arranging meetings with the coastal municipalities. Most of the information that has been requested from the municipalities is already available in several studies conducted by DEP.
3. Because of the lack of coordination and general agreement between our respective agencies noted above, it is our opinion that meetings with the coastal municipalities and detailed press releases have been premature.
4. To a large extent, the study may be investigating structural flood management alternatives that could be inconsistent with state policy and statutes. There are numerous projects that the municipalities have identified for the Corps in their initial meetings for which the state could not issue a coastal management

federal consistency concurrence. We are most interested that the study focus on non-structural alternatives as intended by our original 1983 request. We are very concerned over a study that would investigate and propose structural flood protection measures that would be inconsistent with state policy. If our desire for a non-structural emphasis cannot be reasonably assured, then, given the potential for irreconcilable conflicts over some structural alternatives, there would seem to be little reason to proceed further with the study.

5. By state law, this Department must be the sole initiator and coordinator for any cooperative flood control project with a federal agency. Therefore it is extremely important that any proposed projects of this type be developed in cooperation with the Department before municipal expectations are raised unreasonably.

At this time, we are not certain that we can endorse the project or approach that the Corps of Engineers is undertaking. It is my recommendation that this study be temporarily suspended until staff from the DEP and the Corps can meet to develop a mutually agreed to and mutually supported study design. While I am sensitive to the Corps' time constraints and the fact that another set of municipal meetings are currently in progress, we request that the effort be suspended and further municipal meetings postponed until our potential differences and conflicts have been reconciled.

I thank you for considering this request. Mr. Arthur J. Rocque, Jr., Director of Planning and Coordination/Coastal Management will serve as the Department's coordinator on this matter. He can be reached at 203-566-7404. He and his staff will work to assure a prompt and coordinated response from this agency so as not to significantly jeopardize the projects overall timing.

Sincerely,


Stanley J. Pac
Commissioner

SJP/rr

cc Joseph Ignazio
Douglas Cleveland
Arthur J. Rocque, Jr.
Hugo Thomas
Benjamin Warner

CONSERVATION COMMISSION
THE WETLANDS AGENCY
THOMAS J. STEINKE, DIRECTOR



Independence Hall
725 Old Post Road
Fairfield, Connecticut 06430
Tel. 203 255-8267

Town of Fairfield

February 9, 1987

Mr. Douglas Cleveland
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02154

Dear Mr. Cleveland:

I am quite interested in your upcoming study of the Fairfield shoreline with respect to hurricane damage potential and alternatives available to minimize its extent.

I would appreciate receiving any background data on this study, as well as a review of its intended intensity, duration and objectives.

Thank you for your consideration in this matter

Sincerely yours,

Thomas J. Steinke

TJS/jh
Enclosure: Newspaper article



Town of Fairfield
FAIRFIELD, CONNECTICUT 06430

Jacquelyn C. Durrell
First Selectman

November 17, 1986

Mr. Joseph L. Ignazio
Chief, Planning Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254-9149

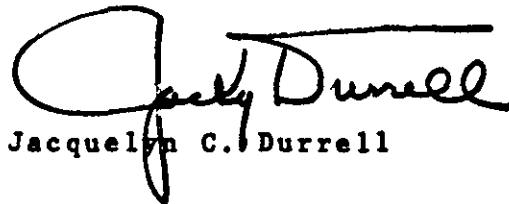
Dear Mr. Ignazio:

Thank you for your letter informing us that the Town of Fairfield will be considered as you review tidal flood damage reduction measures.

I have asked Joe Devonshuk, our Director of Town Plan and Zoning, to be the contact for Fairfield. Mr. Devonshuk can be reached at 255-8248. I am sure you will find Joe to be knowledgeable and cooperative.

If there is any way I can be of assistance, please do not hesitate to contact me again.

Sincerely,



Jacquelyn C. Durrell

cc: Joe Devonshuk



TOWN OF STRATFORD

Ronald W. Owens
Town Manager

CONNECTICUT 06497

203-385-4001

November 14, 1986

Joseph L. Ignazio,
Chief, Planning Division
Department of the Army,
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Ma. 02254-9149

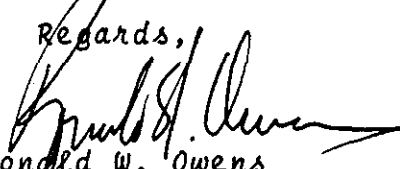
Dear Mr. Ignazio:

The Town of Stratford is interested in possible participation with the Army Corps of Engineers concerning flood reduction measures for flood prone areas in Stratford.

The contact person for the Town is Charlie Buynovsky, Engineering Supervisor, and Mr. Buynovsky will be available to assist the Corps in the reconnaissance study about to be undertaken.

I would also request that in addition to coordination with Mr. Buynovsky that you continue to keep this office informed of the study's status.

Regards,


Ronald W. Owens

cc: Charlie Buynovsky



"COUNCIL-MANAGER GOVERNMENT SINCE 1921"



THOMAS W. BUCCI
Mayor

OFFICE OF THE MAYOR
CITY OF BRIDGEPORT, CONNECTICUT
45 LYON TERRACE
BRIDGEPORT, CONNECTICUT 06604

November 13, 1986

Joseph L. Ignazio
Chief, Planning Division
Basin Management Division
Department of the Army
424 Trapelo Road
Waltham, Massachusetts 02254-9149

Dear Mr. Ignazio:

In response to your letter of October 27, 1986 requesting a contact person for the reconnaissance study your office is conducting, I have named the following person:

Mr. Robert C. Kalm, P.E.
City Engineer
City Hall
45 Lyon Terrace
Bridgeport, CT 06604.

You may forward all future correspondence to his attention.

Sincerely,

A handwritten signature in cursive script, reading "Thomas W. Bucci".

THOMAS W. BUCCI
MAYOR

cc: Robert Kalm

TWB/tmw

DEVELOPMENT ADMINISTRATION

City of Bridgeport

THOMAS W. BUCCI
Mayor
EDWARD J. MUSANTE, JR.
Dev. Administrator



45 LYON TERRACE
BRIDGEPORT, CONNECTICUT 06604
TEL. 576-7755



Associates:
MICHAEL W. FREIMUTH
Economic Development
JOEL R. KENT
Programs
ANDREW J. MAYO
Neighborhood Development
STEPHEN R. SASALA
Planning
REGINALD F. WALKER
Physical Development

November 10, 1986

Mr. Douglas A. Cleveland
Basin Management Branch
Department of the Army
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Re: Tidal Flood Damage Reduction/CT Coast

Dear Mr. Cleveland:

In response to Mr. Joseph Ignazio's October 27th letter regarding the above referenced topic and the request that a local contact person be identified, please direct all project related material to Mr. Michael P. Nidoh, Assistant Planning Director, 45 Lyon Terrace, Bridgeport, CT 06604. Thank you for your attention to this matter.

Cordially,

Stephen R. Sasala II, AICP
City Planning Director

SRS/mr

cc: Mayor Bucci
Michael Nidoh

OPERATING AGENCIES

Building Department

Housing Code Enforcement

Housing Site Dev. Agency

Planning Department

Redevelopment Agency



WESTPORT CONNECTICUT

CONSERVATION COMMISSION

TOWN HALL-110 MYRTLE AVENUE

WESTPORT, CONNECTICUT 06880

November 7, 1986

Dept. of the Army
New England Division
424 Trapelo Road
Waltham, MA. 02254-9149

Re: Tidal Flood Damage

Dear Mr. Ignazio:

We have received a copy of your October 27, 1986 correspondence to the First Selectman.

As the Conservation Department is involved in Erosion mitigation in regard to flooding, we would appreciate being placed on your mailing list for further information on your planning study.

Thank you for your attention to this matter.

Sincerely,

A handwritten signature in cursive script that reads "Frances Pierwola".

Frances Pierwola
Conservation Director

FP:jm



OFFICE OF THE CHIEF ADMINISTRATIVE OFFICER
CITY OF NEW HAVEN

JOHN DeSTEFANO, JR.
CHIEF ADMINISTRATIVE OFFICER

770 CHAPEL STREET
(ENTRANCE: 95 ORANGE STREET)
NEW HAVEN, CONNECTICUT 06510
(203) 787-8278

November 4, 1986

Mr. Douglas A. Cleveland
Basin Management Branch
Department of the Army
New England Division,
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254-9149

Dear Mr. Cleveland:

The City of New Haven is in receipt of Mr. Joseph L. Ignazio's letter of October 27, 1986, to Mayor DiLieto concerning the New England Division of the Corps of Engineers' study of flood prone areas along the Connecticut coast. Thank you for informing the City of these planned activities and please be advised that should the City be of assistance to your project that you may contact me at (203) 787-8278.

Very truly yours,

John DeStefano, Jr.
Chief Administrative Officer

cc: Leonard Smith



United States Department of the Interior

FISH AND WILDLIFE SERVICE

ECOLOGICAL SERVICES

P.O. BOX 1518

CONCORD, NEW HAMPSHIRE 03301

Joseph L. Ignazio
Chief, Planning Division
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254-9149

NOV 04 1986

Dear Mr. Ignazio:

This responds to your October 27 letter to Mr. Howard Larsen, Regional Director of the Fish and Wildlife Service, regarding the proposed Connecticut tidal flood reduction studies. Mr. Larsen forwarded your letter to me since my office is responsible for coordinating with the Corps on all Federal projects in New England. Please direct your future correspondence to this office so that we may respond in a more timely and efficient manner.

We look forward to assisting the Corps as your planning activities progress.

Sincerely yours,

Gordon E. Beckett
Supervisor
New England Area



TOWN OF EAST HAVEN
HONORABLE ROBERT M. NORMAN, MAYOR
250 MAIN STREET
EAST HAVEN, CONNECTICUT 06512

October 30, 1986

Planning Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254-9149

Attention: Joseph L. Ignazio, Chief
Re: Your letter of October 27, 1986

Dear Mr. Ignazio:

The East Haven "Point of Contact" for your planning activities will be Charles A. Boster, Town Planner.

Thank you for keeping East Haven informed.

Sincerely,

Robert M. Norman
Mayor

cc: Art Rocque, DEP
RMN/ks



STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION



November 7, 1983

Colonel Carl B. Sciple
Division Engineer
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA. 02254

Dear Colonel Sciple:

Recently, Richard Quinn of your office consulted with my staff concerning new CE activities in Connecticut. As a result of that discussion, I would like to recommend two endeavors.

First, this agency very much endorses the strategy to have your agency follow-up the Long Island Sound Thamesville Tidal - Flood Management Water Resources Study by looking into non-structural techniques, especially flood warning systems for the Thamesville area. While I endorse additional efforts in the Thamesville area, it is important to note I believe implementation of a project in Thamesville must begin soon. The town of Norwich, of which Thamesville is a part, has been the subject of many flood problem studies; but to date no project has been implemented. If the CE is to initiate additional study in this area, it is imperative that it be part of detailed project planning that is directly related to project implementation. Additional flood studies in the Norwich area that are not connected directly to implementation would not be in the best interests of the state or the residents of the Norwich area.

Secondly, I am providing a list of priority areas for additional studies along our coastline. The list has been developed using a new classification of flood hazards by drainage basin. This process has resulted in the ranking of drainage basins according to their flood susceptibility. I am pleased that Grant Kelly of your staff has been involved in this project as a member of the overseeing committee. While the classification is new, and will be refined, I do believe that it represents the most objective means yet devised of ranking our flood problems. Specifically, I would like to request that the CE begin new studies to delineate flood management alternatives for coastal areas. While there are many coastal communities which have significant flood hazards, I believe that the areas most vulnerable to flood losses are, in alphabetical order:

1. East Haven and New Haven shoreline.
2. Fairfield shoreline, especially Fairfield Beach and Pine Creek.
3. Milford and West Haven shoreline, especially Bay View (Milford), the mouth of the Housatonic River (Milford), and Prospect Beach (West Haven).
4. Old Saybrook and Westbrook shoreline, especially Grove Beach (Westbrook).

Phone:

165 Capitol Avenue • Hartford, Connecticut 06106

An Equal Opportunity Employer

Once again, I thank you and your staff for working so closely with this agency in seeking solutions to our flood problems. I am looking forward to initiating new projects with your agency in the near future. As with all flood related work, please contact Benjamin Warner, Director of my Water Resources Unit (203-566-7220) if you have any questions on the technical aspects of my requests.

Sincerely yours,


Stanley G. Pac
Commissioner